104

OVERSIGHT REVIEW OF RESEARCH LABORATORY PROGRAMS AT THE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

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Oversight Review of Research Labora...

HEARING

BEFORE THE

SUBCOMMITTEE ON TECHNOLOGY

OF THE

COMMITTEE ON SCIENCE

U.S. HOUSE OF REPRESENTATIVES

ONE HUNDRED FOURTH CONGRESS

SECOND SESSION

JUNE 25, 1996

[No. 62]

Printed for the use of the Committee on Science

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*Ranking Minority Member
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CONTENTS

WITNESSES

Page

June 25, 1996:

Shukri A. Wakid, Director, Computer Systems Laboratory, and Acting Director, Computing and Applied Mathematics Laboratory, National Institute of Standards and Technology 3

Ralph Z. Roskies, Chair, National Research Council, Panel for Information Technology 14

Charles N. Brownstein, Executive Director, Cross-Industry Working Team, Corporation for National Research Initiatives 50

Robert E. Hebner, Acting Deputy Director, National Institute of Standards and Technology 70

V. Thomas Rhyne, Chair, National Research Council Panel for Electronics and Electrical Engineering 88

James A. Glaze, Vice President, Technology Programs, Semiconductor Industry Association 134

OVERSIGHT REVIEW OF RESEARCH LABORATORY PROGRAMS AT THE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

TUESDAY, JUNE 25, 1996

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE,
SUBCOMMITTEE ON TECHNOLOGY,
Washington, DC.

The Subcommittee met, pursuant to notice, at 1:11 p.m., in Room 2325, Rayburn House Office Building, Hon. Constance A. Morella, Chairwoman of the Subcommittee, presiding.

Mrs. MORELLA. I am going to call to order the Technology Subcommittee of the Science Committee for this hearing that we have on research laboratory programs at the National Institute of Standards and Technology. I appreciate the willingness of panel number two to become panel number one. That just shows your adaptability, and I appreciate that.

Today's hearing is the third and the final one in a series of hearings to review the intramural laboratories at the National Institute of Standards and Technology.

As the Council on Competitiveness noted in its recent report entitled, "Endless Frontier, Limited Resources", the United States research and development enterprise finds itself in a wrenching period of change with the end of the Cold War, the globalization of the world economy, and the drive to eliminate the Federal deficit. This environment creates both an unprecedented opportunity and a significant challenge for NIST.

On the one hand, NIST is the lead Federal laboratory in interacting with industry, having the statutory mission to promote U.S. economic growth, by working with industry to develop and apply technology, measurements, and standards. Further, as the report noted, research and development partnerships are the key to meeting this challenge. However, Federal institutions are increasingly challenged to keep pace with technological change and global market forces, particularly in an era of shrinking government budgets.

So today's hearing will focus on the Information Technology Laboratory and the Electronics and Electrical Engineering Laboratory. In many respects, these two laboratories support industrial sectors that are at the forefront of our nation's technological revolution and are defining our global economic competitiveness.

The information industry annually invests over $30 billion in research and development. Seventy-eight percent of computer industry revenues comes from products that have been on the market for less than two years. In recognition of the need to focus on this large, fast-moving industry, NIST is proposing to merge two existing laboratories to form the Information Technology Laboratory.

Likewise, the electronics industry is growing rapidly and currently accounts for nearly 11 percent of U.S. GDP. For example, the domestic semiconductor industry is recovering from a slump in the mid-1980s surpassing the Japanese share of the global semiconductor market in 1993 for the first time in eight years. This transformation has been aided by the semiconductor industry's development of a Technology Roadmap to more efficiently utilize the nation's technology resources, including NIST.

We are fortunate to have with us today, on what will then become the second panel, the Directors of these two NIST laboratories to describe how their laboratories are responding to the challenges. We also have the Chairs of the National Research Council panels that perform the annual detailed assessment of the intramural NIST laboratory programs. Also, we are pleased to have representatives of NIST's important customers in industry to give their perspectives on the value of the NIST activities.

So due to our flight delay for Dr. Rhyne on the Electronics and Electrical Engineering Laboratory panel, we are going to hear first from the Information Technology Laboratory panel. I look forward to the testimony of the witnesses and I am now happy to recognize the distinguished ranking member of the Subcommittee, Mr. Tanner.

Mr. TANNER. Thank you, Madam Chairwoman, and I'll be very brief.

I want to welcome you all. This is the third hearing on the NIST laboratory programs and I was glad to see the chair reference the Council on Competitiveness report, which strongly recommended that the old distinction between basic and applied research be dispensed with. I might also add it recommended for our consideration the elements of the ATP and EMIPRI programs, as well, but that was not to be.

Anyway, NIST's role is to remove measurement barriers that individual companies cannot overcome because they lack one or more of NIST's special characteristics in partial position, recognized measurement capability, direct access to national standards, or authority as the lead U.S. agency for measurements. These characteristics permit NIST to do what individual companies cannot. Gain access to industry information needed to resolve industry-wide measurement problems, develop measurement solutions and national reference standards that benefit industry as a whole and gain acceptance of those solutions by U.S. industry and its international customers so that U.S. products can be sold worldwide.

I continue to believe that NIST is the stealth agency of the Federal Government, little understood, yet one of the linchpins of U.S. economic strength and competitiveness. I believe that. That is why I'm on this Committee. I want to take this opportunity to commend the NIST employees who have labored under some stress the last year or so, and I want to say once again that the work that you all do is very important to this country and it's important to what we do as a country in terms of economic industry growth and competitiveness in the world economy. Thank you, witnesses, for being here today.

Thank you.

Mrs. MORELLA. Thank you, Mr. Tanner.

We will start off and hear from each of you, and I think we'll do it, if there's no objection, in the order from your left to right. So we'll start off with Dr. Shukri Wakid, who is the Acting Director of the Information Technology Laboratory at the National Institute of Standards and Technology in Gaithersburg. Then we will hear from Dr. Ralph Roskies, who is Chair of the National Research Council Board on Assessment of NIST Programs Panel for Information Technology. Then we will hear from Dr. Charles Brownstein, Executive Director, Cross-Industry Working Team, Corporation for National Research Initiatives, out of Reston, Virginia.

Dr. Wakid, we will start with you.

STATEMENTS OF DR. SHUKRI A. WAKID, ACTING DIRECTOR, INFORMATION TECHNOLOGY LABORATORY, NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY, GAITHERSBURG, MARYLAND; DR. RALPH Z. ROSKIES, CHAIR, NATIONAL RESEARCH COUNCIL BOARD ON ASSESSMENT OF NIST PROGRAMS PANEL FOR INFORMATION TECHNOLOGY, WASHINGTON, D.C.; AND DR. CHARLES N. BROWNSTEIN, EXECUTIVE DIRECTOR, CROSS-INDUSTRY WORKING TEAM, CORPORATION FOR NATIONAL RESEARCH INITIATIVES, RESTON, VIRGINIA

Dr. WAKID. Chairwoman Morella and Members of the Subcommittee, thank you for allowing me to speak. I would like to briefly describe the key role that the NIST laboratories play in providing U.S. industry needs for measurement and standards.

The Computer Systems Laboratory and the Computing and Applied Mathematics Laboratory provide the technical underpinnings and enabling tools that accelerate getting research into the marketplace and help everyone do their job better.

Information technology is an enabling technology that is becoming an essential tool for doing business and is changing the way we do business. We need to step up to this new opportunity. To be competitive, it's essential that we ease the barriers that keep information technology from being a universal tool for business.

There are barriers to the usability of the technology. There are barriers to the interoperability of the technology across different vendors' systems, barriers to the scalability of the technology to allow widespread access, and there are barriers to the security of the technology to make it dependable for business transaction.

We develop test methods that small and large companies need and that the users require. These tests expose and ease the barriers that I mentioned. In many cases, industry, recognizing our neutrality and strong technical programs, requests our involvement and leadership in test development.

As an example, imagine how useful it would be for us to talk to computers and get relevant information. We provide researchers with the open pre-competitive tests that allow the objective comparison of different approaches and enable the feasibility of applying such research. We develop tests such as this for human-machine interfaces, of which speech is an example.

We also develop tests for software diagnostics such that the quality of U.S. software is reliable. In critical safety systems, software must be dependable so that the information technology can be used with assurance.

We develop tests for conformance to standards to capture the technical description of the standards and ensure compliance and consistency in conforming to these standards. ISDN, Integrated Services Digital Network Technology, is an example for which we developed conformance tests.

We also provide services to NIST scientists, enabling them to use applied mathematics and statistics and to explain to the engineering and scientific community how to apply these underpinning methods to predict and expand their industry to new domains. This means that they do not have to build very expensive prototypes to understand the behavior of these new technologies.

Finally, we have a Federal role that is mandated by Congress. We help Federal agencies with the use and implementation of standards as well as with promoting security mechanisms for unclassified and sensitive government information and getting the unique requirements of the government in coherence with industry needs.

Let me submit for the record my testimony, and thank you.

[The prepared statement of Dr. Wakid follows:]

U.S. DEPARTMENT OF COMMERCE

TECHNOLOGY ADMINISTRATION

STATEMENT OF SHUKRI A. WAKID

DIRECTOR, COMPUTER SYSTEMS LABORATORY

AND

ACTING DIRECTOR, COMPUTING AND APPLIED MATHEMATICS LABORATORY

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

BEFORE THE

SUBCOMMITTEE ON TECHNOLOGY

COMMITTEE ON SCIENCE

U.S. HOUSE OF REPRESENTATIVES

JUNE 25, 1996

Chairwoman Morella and Members of the Subcommittee:

This is a time of challenge and a time of change for the National Institute of Standards and Technology in the area of information technology. The challenge is to build a new organization that will strengthen NIST's ability to provide measurements and related standards for our nation's information technology industries. To meet this challenge, we plan to establish an Information Technology Laboratory that will be built on the foundation of the existing Computer Systems Laboratory (CSL) and the Computing and Applied Mathematics Laboratory (CAML). I am honored to speak to you today about how CSL and CAML are working with industry to address critical problems in information technology which demand the generic solutions that we are uniquely qualified to provide.

The NIST laboratories have a limited but critical role in helping to meet U.S. industry's needs for measurement and standards. The Computer Systems Laboratory and the Computing and Applied Mathematics Laboratory provide the technical underpinnings and enabling tools that accelerate getting products into the marketplace and help everyone do their job better.

Information technology is an enabling technology that is being embedded in consumer products, household appliances, desktop computers, and network services. It is becoming an essential tool for doing business, and is changing the way that we do business.

We direct our work to overcome the barriers to the development and use of information technology systems that are secure, interoperable, easily usable, and scalable. Inadequate security is a serious barrier to the use of open networks for exchanging sensitive information, or for carrying out high value transactions. Systems that lack interoperability and are difficult to use make it frustrating for users who would like to change their traditional ways of doing business but are reluctant to adopt new technology. Even successful applications often cannot be used on a mass basis because they cannot scale up to larger proportions.

We are developing accurate and reliable tests, test methods, and reference data, which are needed by many producer and user organizations to overcome these barriers. Our work is often done in collaboration with industry, and always done with objectivity and neutrality. Our activities cover a broad range of networking, security, and advanced information technologies; mathematical, statistical and computational sciences; and the operation and modernization of computing and telecommunications facilities within NIST.

Ongoing Responsibilities

Like our counterpart NIST laboratories, our main emphasis is on the development of tests, test methods and reference data. But we also continue to carry out some basic functions. CSL continues to be the government's source of technology and expertise for technical information technology standards including those needed to protect sensitive, but unclassified information. CAML continues to provide computational, supercomputing, networking and administrative computing services to all of NIST. The laboratory develops and applies mathematical and statistical algorithms and models in collaboration with NIST scientists and engineers, and their industrial collaborators. These are important, ongoing responsibilities.

Three Focus Areas

Today, I would like to discuss three areas. The first area is test methods for communications, human-machine interfaces, computer security, and software. For security and software especially, these activities represent a shift from past efforts. We are moving from the development of standards for maturing technologies to the development of open, precompetitive tests and test methods. Although both needs are important, we have come to realize that reliable test methods help to stimulate the growth and adoption of new technology. This is where our programs can make a real difference.

The second focus area is algorithms and analytic tools for mathematics and statistics to improve understanding of complex processes and analysis of data. The third focus area is our responsibility to federal agencies under the Information Technology Management Improvement Act of 1996 and Office of Management and Budget Circular A-130.

Test Methods

Our work on test methods, tests, standard reference data, and tests for conformance to written standards helps producers develop better, higher quality products and helps users evaluate these products. Information technology systems are so complex that it is virtually impossible to evaluate correctness or performance of the various parts without automated tests and methods. These tests and methods are most useful and cost effective when they are widely adopted, but they are beyond the reach of individual companies or user organizations to develop.

As a neutral party, we are often asked to help industry standards writing organizations by developing tests that capture the technical description of the written standards. The tests help to assure compliance and consistency of products that implement the standards. We do not set the standards. Industry sets standards. We focus on advanced technologies that are not widely implemented or not available in commercial off-the-shelf products.

Here are some examples of how our work is used by a broad spectrum of organizations to advance the development and use of new technology. We chose to participate in these projects because they fit into our unique mission, have a high probability of success, and will have a high potential impact if successful.

- We have been collaborating with industry's Digital Audio/Video Interoperability Council (DAVIC) to develop tests for the interoperability of different video applications for the home. Interoperability is critical to the delivery of digital video information through a variety of different networks that have different requirements for handling data.

- We have been cooperating with the ATM Forum, an industry consortium developing standards for Asynchronous Transfer Mode (ATM) technology. We are contributing to the development of tests for the interoperability of products and services based on this new, high speed digital technology for networks. ATM will deliver a complex mix of digital information including text, images, video, and sound to the desktop if consistent standards can be developed and used properly.

- We were invited by a standards committee of the Institute of Electrical and Electronic Engineers (IEEE 802.14) to help the committee evaluate proposals for protocol standards for coaxial cable modems. This equipment is expected to bring a new range of interactive TV and other interactive computing services to consumers.

- We developed a method for evaluating the performance of optical character recognition (OCR) systems that process handprinted text. These systems automate the conversion of handprinted letters and numbers to a digital form for computer processing. Automatic recognition of different styles of handprinting continues to be a tough technical challenge. We have distributed our evaluation method and a collection of many different samples of hand printed text to more than 150 U.S. companies, small and large. Many of these organizations are using the system to test their own products or to develop new products that perform better and faster.

- We have produced tests for evaluating the performance of speech recognition systems. Speech recognition technology has long been thought to be a good way for humans to interact with computers by speaking to them. But these systems must still be improved to work no matter who the speaker is and to recognize words spoken by humans using their natural speech patterns. Major companies and universities involved in speech recognition research have relied on our tests to evaluate and improve their systems. Our sponsors of this work cite the tests as influential drivers of continuing improvements that are occurring in automated speech recognition systems. The market potential is enormous.

- We are developing measures of performance for a prototype system that will enable humans to get information from a large computerized library collection of data. This system will demonstrate how people could ask questions to the computer and receive responses about the contents of the documents in the library. We expect that the measures of performance will help to advance the commercial availability of such systems.

- Our work with the North American Integrated Services Digital Network (ISDN) Users Forum to develop standards and conformance tests for ISDN technology made significant contributions toward the development of the technology. This was the conclusion of a study done on the Forum's impact on U.S. industry. The study, based on industry estimates, projected the economic rate of return from our investment in ISDN to be 156 percent.

Mathematical, Computational and Statistical Sciences

Next, I would like to turn to our activities in mathematical, computational, and statistical sciences. A recent report on the needs of the chemical industry for new technology specifically identified improvements in modeling and the application of information technology as essential to the chemical process industry. These requirements permeate many other industry sectors as well.

NIST mathematicians model physical phenomena to enable our scientists to visualize and understand them. The methodology and algorithms developed to solve NIST's own research problems are also shared with industry and academia. NIST statisticians develop and apply new experiment designs to help scientists and engineers work productively, model their data, and assess its uncertainty so that their collaborators can draw correct conclusions from their experiments. For example, NIST statisticians, mathematicians, and engineers are developing a new calibration model for Coordinate Measuring Machines that can be used to improve the determination of part dimensions in manufacturing. Since over 20,000 Coordinate Measuring Machines are in use throughout the country, better modeling provided substantial savings to U.S. industry through improved quality and productivity and significant reductions in waste.

NIST's Guide to Available Mathematical Software (GAMS) has been a very successful effort to disseminate information about mathematical software that can be used in scientific and engineering applications. GAMS helps scientists and engineers locate and use nearly 10,000 reusable problem-solving modules from currently available mathematical software packages. Since we made it available on a World Wide Web server in April 1994, GAMS has received more than 1,800,000 inquiries, and has been awarded the highest, 4-star rating by the McKinley Group, a private organization that rates Web services.

We have developed a program that will extend our expertise in modeling and simulation to more directly assist scientists and engineers in industry. For example, we plan to develop reference data sets that will help software developers improve the reliability of their mathematical and statistical software products. Currently, there are very few such tools available. The algorithms and the software are difficult to test objectively; errors occur often in specialized circumstances that are related to the problem to be solved. We plan to identify and make available neutral and objective test data to assist developers, researchers, and users in making these difficult evaluations.

Federal responsibilities

Last, I would like to reaffirm our commitment to serving other federal agencies. The research in test methods and measurements that I discussed earlier will effectively serve the federal government. These test methods will drive the development of higher quality and better hardware and software products. This will have a significant payoff for federal buyers of these products, and will also benefit private sector users.

I would like to conclude with a brief discussion of our responsibilities for computer security, and specifically for cryptography. You are probably well aware of the risks to our nation's and our government's computer resources, and the challenges in securing those resources. NIST plays a key role, under the Computer Security Act of 1987, in developing standards and guidelines to assist federal departments and agencies in securing their automated information assets.

Adequately and appropriately securing automated information resources is not a simple or one-dimensional task. There is no silver bullet, such as cryptography, that renders a system and the data it processes secure. Adequately protecting a system requires that the risks be studied, and appropriate controls be selected and implemented correctly. These include management, technical and operational controls, encryption, authentication, and incident handling. Implemented correctly, such controls operate synergistically to provide security.

Our computer security program is currently focused on five key areas where we believe we can make the greatest contribution to solving the overall problem:

- advanced authentication technology,
- security criteria and evaluation,
- secure Internet and network connectivity,
- cryptographic technologies, and

- public key infrastructure activities.

Our efforts in cryptography and particularly encryption receive the most public attention. Although encryption can be used as a cost-effective tool to protect data against unauthorized disclosure, it can also be used to thwart the legitimate missions of law enforcement and national security agencies. We have become involved in this issue because of our legislative mandate to provide agencies with sound security advice. At the same time, we must meet our obligations not to take actions that may harm society.

We work with industry, law enforcement, and security officials to help them in their efforts to develop sound cryptographic techniques that balance these interests. Many of the techniques that we have developed have been voluntarily adopted by private sector organizations. An example is the Data Encryption Standard, which is based on a commercially developed technique and which long ago became a voluntary industry standard for protecting computer information.

As a leader in computer security for the federal government, we are often asked by governmental organizations of other countries to participate in joint projects. We are currently cooperating with Canada, France, the UK, Germany, and the Netherlands to develop common evaluation criteria for computer security products and systems. This cooperative approach is expected to pay off for all participants. One uniform, internationally accepted method for evaluating computer security products would lower costs for producers, increase the availability of products for users, and help to broaden the global market for U.S. products.

Summary

We are committed to expand and strengthen our collaboration with industry to carry out our programs. We are committed to advancing the development of pivotal, forward-looking technologies by removing impediments caused by the lack of appropriate measurement technology or by inappropriate standards. The timing is right. Interoperability and security of information technology products and services are essential to a global marketplace for U.S. industry. Better use of new mathematical and statistical algorithms and models for data analysis and decision making will help the United States move forward aggressively.

Information technology is a big $630 billion industry in the U.S. We cannot ignore that large part of the economy and the opportunity that it provides for our industry.

We believe that we can be successful in accomplishing our goals, and that our work at NIST can make a difference. Our work is generic. It provides the infrastructure that individual organizations do not invest in by themselves, but which enable all to move forward in achieving secure, interoperable, usable, and scalable systems. If we are successful in these efforts, our industry will be well positioned to meet future challenges and changes.

BIOGRAPHY

SHUKRI A. WAKID

Shukri A. Wakid is the Director of the Computer Systems Laboratory and the Acting Director of the Computing and Applied Mathematics Laboratory at the National Institute of Standards and Technology (NIST). Dr. Wakid is responsible for reorganizing the two laboratories into the planned Information Technology Laboratory. He manages programs in Advanced Network Technologies, Computer Security, Information Access and User Interface, Information Systems Architecture, Applied Mathematics, Statistics, High Performance Systems and Services, and Information Services. The two laboratories have more than 400 scientists and support staff.

Shukri's previous work experience includes telecommunications networks and very large scale integration (VLSI) work at Bell Laboratories and Atomic Physics research at NASA and the University of Pittsburgh. He was awarded a Ph.D. in Atomic Physics in 1971.

Selected by **CommunicationsWeek** among the top 25 communication visionaries (November 17, 1989). Also selected as a "Newsmaker" by **Data Communications** (July 1988). He received the Presidential Rank Award of Meritorious Executive in 1993 and the Department of Commerce's Silver Medal in 1992.

Mrs. Morella. Thank you, Dr. Wakid. Your entire testimony that you submitted will be included in the record in its totality.

Dr. Roskies?

STATEMENT OF DR. RALPH Z. ROSKIES

Dr. ROSKIES. Chairwoman Morella and Members of the Subcommittee, I am pleased and privileged to address you today as Co-Chair of the National Research Council's Panel for Information Technology, which conducts an annual assessment of the programs of the Computing and Applied Mathematics Laboratory and the Computer Systems Laboratory at the National Institute of Standards and Technology.

My own training is in theoretical high energy physics. I am a professor of physics at the University of Pittsburgh and I am Scientific Director of the Pittsburgh Supercomputing Center. I have been involved in the National Research Council assessments of the NIST laboratories since 1991. The Panel for Information Technology currently has 24 members, of whom seven work in academia, 12 in industry, and five work in other sectors, such as government or private non-profits.

Historically, NIST has played an important role in the development of information technology by identifying and developing key enabling technologies and technology components, by establishing standards and protocols, and by establishing technical specifications for Federal procurement.

More recently, the unprecedented pace of development and rapid commercialization of information technology has meant that NIST must redefine its role in order to respond more effectively to the needs of industry. Rather than defining standards, NIST should serve as a facilitator for standards development and as a conformance tester, emphasizing interoperability, reliability, and usability.

Accordingly, the two laboratories at NIST that have traditionally focused on computer technology, computer science, and applied mathematics are being merged into one organization unit known as the Information Technology Laboratory. The new unit will have both the important task of supporting advanced computational and analytical needs of the other science and engineering units within NIST and facilitating the growth of information technology through research and development in advanced networking technologies, visualization, human-machine interfaces, computer and network securities, and standards and technology to support electronic commerce.

The panel supports the decision of NIST management to merge the Computing and Applied Mathematics and Computer Systems Laboratories into a new Information Technology Laboratory that will be more tightly focused on the needs of industry. While the final shape of an Information Technology Laboratory will be influenced by many factors which we cannot yet foresee, we believe that this reorganization will help NIST respond more effectively to the nation's needs for standards and technology in the information technology arena.

Thank you for the opportunity to appear before you today.

[The prepared statement and attachment of Dr. Roskies follow:]

Testimony by Dr. Ralph Z. Roskies, Chair
National Research Council
Panel for Information Technology
to the hearing on

"Oversight Review of Research Laboratory Programs at the
National Institute of Standards and Technology"

Held by the
Subcommittee on Technology, Committee on Science
U.S. House of Representatives
~~April 30, 1996~~
JUN 25 1996

Ms Chairwoman and Members of the Subcommittee:

I am pleased and privileged to address you today as co-Chair of the National Research Council's (NRC) Panel for Information Technology which conducts an annual assessment of the programs of the Computing and Applied Mathematics Laboratory and the Computer Systems Laboratory at the National Institute of Standards and Technology (NIST). My own training is in theoretical high energy physics, and I am a Professor of Physics at the University of Pittsburgh and Scientific Director of the Pittsburgh Supercomputing Center. I have been involved in the NRC's assessment of the NIST Laboratories since 1991 The Panel for Information Technology currently has 24 members, of whom 7 work in academe, 12 work in industry, and 5 work in other sectors, such as government or private non-profits.

I would like to read into the record the accompanying 1995 Report of the Panel for Information Technology which evaluates in detail issues of balance, effectiveness, technical quality, impact on industry and management of each of the divisions of these two laboratories.

NIST has been engaged in the development of standards for and key components of computer and information technology since this technology and its precursors first emerged. Much of the immediate post-World War II progress in numerical analysis and special functions came out of the National Bureau of Standards, now NIST Likewise, NIST has played an important role in developing standards, measures, and testbeds such as digital signatures and data interchange formats that make a national information infrastructure possible.

Historically, NIST has played an important role in the development of information technology by identifying and developing key enabling technologies and technology components, by establishing standards and protocols, and by establishing technical specifications for federal procurement More recently, the unprecedented pace of development and rapid commercialization of information technology has meant that NIST must redefine its role in order to respond more effectively to the needs of industry. Rather than defining standards, NIST should serve as a facilitator for standards development, and as a conformance tester, emphasizing interoperability, reliability and usability. Accordingly, the two laboratories at NIST that have traditionally focused on computer technology, computer science, and applied mathematics are being merged into one organizational unit known as the Information Technology Laboratory.

The new unit will have both the important task of supporting the advanced computational and analytical needs of other science and engineering units within NIST, and facilitating the growth of the information technology through research and development in advanced networking technologies, visualization, human-machine interfaces, computer and network security, and standards and technology to support electronic commerce

The Panel supports the decision of NIST management to merge the Computing and Applied Mathematics and Computer Systems Laboratories into a new Information Technology Laboratory that will be more tightly focused on the needs of industry. In fact, the Panel's chief recommendation in its 1995 assessment was that the merger proceed more quickly. Since the time of the Panel's site visit to NIST in April 1995, Shukri Wakid has been appointed Acting Director for both of the two units which will eventually form the Information Technology Laboratory, and planning for the joint laboratory has accelerated.

While the final shape of an Information Technology Laboratory will be influenced by many factors which we cannot yet foresee, I believe that this reorganization will help NIST respond more effectively to the nation's needs for standards and technology in the information technology arena.

Thank you for the opportunity to appear before you today.

Fiscal Year 1995 Assessment of the Information Technology Laboratory by the Panel for Information Technology

Panel Members

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Submitted for the panel by its Co-Chairs, Ralph Z. Roskies and Michael B. Spring, this assessment of the fiscal year 1995 activities of the Information Technology Laboratory is based on site visit by the panel on May 1-3, 1995, and on the annual report of the laboratory.

LABORATORY OVERVIEW

Introduction

The Computer Systems Laboratory (CSL) and the Computer and Applied Mathematics Laboratory (CAML) are due to be merged into a single entity that will be known as the Information Technology Laboratory (ITL). As of the time of this assessment, the necessary approvals from the Congress and the Department of Commerce for this planned merger have not been gained nor has a director for the new laboratory been identified.

What follows is an assessment of the divisions of the two constituent laboratories, the Computer Systems Laboratory and the Computer and Applied Mathematics Laboratory. In light of the unique nature of the assessment this year, the overall laboratory assessment focuses on the planning for the new Information Technology Laboratory, and the technical evaluations are given in the divisional assessments.

Planning for the Information Technology Laboratory

The panel recognizes the difficult task faced by the divisions of the two laboratories in carrying out their mission during a period of planning for a broader and refocused mission as part of the future Information Technology Laboratory. This also occurs at a time in which most of the divisions must prepare to move their operations to a new off-campus location designated as NIST North. At the same time, the panel believes that the planning effort for the new Information Technology Laboratory must move forward more rapidly. Information technology is a fast moving field, and NIST must become more agile and more positively engaged if it is to play a significant role in this area. Although the laboratories and the divisions have worked diligently to move forward with the planning process, they are now at a point where further progress requires dedicated leadership at the laboratory level. It is important that a director for the Information Technology Laboratory be appointed immediately, on an interim basis if necessary, in order to lead the process of shaping the new laboratory. Although the current directors of the Computer Systems Laboratory and the Computer and Applied Mathematics Laboratory have cooperated in the development of the Information Technology Laboratory, it has been difficult for them to identify opportunities for the new laboratory and infuse the staff with enthusiasm at the prospect of playing a significant role in the development of a national information technology infrastructure.

Although there is considerable dynamism at the division and group level, uncertainty about the future course of the Information Technology Laboratory and the slow pace of the planning process have had a negative impact on morale. The lack of direction resulting from NIST's failure to identify a director for the new laboratory has placed a serious constraint on the priority-setting process at the laboratory level and has also negatively affected the planning process at the division level. The goals of the new laboratory must be articulated well enough for the divisions to incorporate them into their own priorities.

In several divisions, historical program interests still dominate the priority-setting process and divisional management needs to be more proactive in setting program directions. At the laboratory level, a planning document has been developed that identifies six areas of concentration for the Information Technology Laboratory: interoperability, security, services, mathematics (including modeling, statistics, and associated software), human-machine interfaces, and applications development. Interoperability and human-machine interfaces are both critical thrusts for the new laboratory. Security is a natural fit to the mission of the new laboratory and to the expertise currently available in the Computer Security Division. The applications development thrust is the least well developed of the six areas of concentration.

The laboratory's planning for the mathematics thrust, which includes statistical and computational sciences, must take account of the special mission of the Statistical Engineering Division and the Applied and Computational Mathematics Division to provide mathematical, statistical, and computational support to other NIST laboratories.

With respect to industrial impact, the potential of the new laboratory is clearly substantial. The existing divisions can identify anecdotal evidence of positive industrial impact, but this often appears to be a consequence of achieving other goals rather than the result of an explicit strategy to improve the competitiveness and productivity of the U.S. information technology industry. With the creation of the new laboratory and its stated goal of enhancing the competitive position of U.S. industry, more deliberate planning for, and evaluation of, industrial impact is required

Recommendations

The following are the panel's recommendations for the Information Technology Laboratory as a whole.

- The director of NIST should set a more specific charge for the Information Technology Laboratory and move with all due speed to appoint a laboratory director.

- All levels of management, from the director of NIST down through division chiefs, should communicate more effectively to the staff the goals of the new laboratory and the opportunities they represent.

- The panel observes that statistical support of metrology, calibration, and Standard Reference Materials (SRMs) and applied mathematical and statistical support of research efforts in other NIST laboratories are essential to the mission of NIST and recommends that these services should be continued regardless of the administrative structure of the Information Technology Laboratory.

- The panel recommends that laboratory and division management take a proactive approach to selecting current laboratory activities and projects so as to optimally position the new Information Technology Laboratory based on an assessment of where information technology will be going in the next 5 years.

Note: Subsequent to the site visit by the 1995 Assessment Panel, the chief of the Advanced Systems Division within the Computer Systems Laboratory was appointed acting director of the Information Technology Laboratory.

Laboratory Responses to Fiscal Year 1994 Recommendations

The following is the laboratory's response to the recommendations of the 1994 Assessment Panel. The 1995 panel commented on those responses where appropriate, and those comments are included here. In fiscal year 1994, the Computing and Applied Mathematics Laboratory and the Computer Systems Laboratory were assessed individually. Recommendations and responses are arranged accordingly.

Computing and Applied Mathematics Laboratory

1994 Panel Recommendation: ". . .[The] panel recommends strongly that division chiefs be intimately involved in developing the mission statement and organizational structure of the merged [Information Technology] laboratory" (p. 233).
Laboratory Response: The planning committee for the Information Technology Laboratory includes all of the division chiefs.

1994 Panel Recommendation: "The panel urges that mathematical and statistical programs be continued under ITL . . ." (p. 233).
Laboratory Response: The planning committee has identified mathematics, statistics, and scientific computing as a strategic program area for the Information Technology Laboratory.

1994 Panel Recommendation: "The panel urges CAML to add new vigor to its expertise by hiring new staff and by expanding its visitor and postdoctoral fellowship program" (p. 233).
Laboratory Response: The Computing and Applied Mathematics Laboratory will continue to encourage visitors and to seek postdoctoral research associates.
1995 Panel Comment: The Computing and Applied Mathematics Laboratory has indeed encouraged visitors and has explored the possibility of contracting out some services.

Computer Systems Laboratory

1994 Panel Recommendation: "CSL management must carefully approach the merger with CAML to form ITL in order to maintain staff morale and support CSL core capabilities. The staff of the two laboratories should work together to define the challenges and opportunities of the merger, providing input on the organization and programs to the NIST director" (p. 202).
Laboratory Response: An ITL Planning Group has been formed and has held regular meetings since September 1994 to review the existing programs and to plan the steps necessary to create the Information Technology Laboratory. CSL and CAML managers meet regularly in joint management meetings.
1995 Panel Comment: Although CSL and CAML managers have worked together on the ITL planning document, there is no evidence that they have explored the opportunities for synergy that this merger could create.

1994 Panel Recommendation: "CSL must work creatively to overcome its severe staffing limitations. Inclusion of part-time faculty and students in the FTE [full-time equivalent] ceiling is counterproductive; guest staffing should be controlled by funding, space, and mutual benefit" (p. 202).
Laboratory Response: CSL continues to use part-time faculty and students where appropriate to carry out program responsibilities. Guest staff members are encouraged when space is available and there are programmatic benefits. Currently, staffing is limited by funding constraints and by FTE ceilings.

1994 Panel Recommendation: "CSL needs larger, more flexible space. . . ." (p. 202).
Laboratory Response: Plans have been developed for a leased building that will provide space for CSL and CAML staff.

1994 Panel Recommendation: "CSL should . . . develop a model for its customer base . . ." (p. 202).
Laboratory Response: CSL and CAML are jointly developing a strategic planning document that covers customer and technology bases, priorities, and methods for measuring results

1994 Panel Recommendation: "Each CSL division should upgrade and perfect its multiyear plans, with detailed activity descriptions, milestones, forecast completion dates, funding sources, staffing, and relations to other NIST projects. CSL divisions should plan jointly. Joint programs involving more than one division (or laboratory) should have a single plan, showing the activities of each division, group, or laboratory" (p. 202)
Laboratory Response: Joint planning among CSL divisions has been ongoing for the past year. The ITL planning document identifies six thrust areas that support participation across the activities of several divisions Fiscal year 1996 and 1997 initiatives were planned on a joint basis and propose work that will be carried out jointly by more than one division.
1995 Panel Comment: Although CSL divisions plan jointly, existing plans vary widely in substantive content, completeness, and format Some divisions have no formal project planning other than minimal information in individual performance plans It would be helpful if a template was developed and distributed to all divisions so that project planning would be facilitated. The Computer Security Division has very good plans, which could be used as a prototype on which to build the template.

1994 Panel Recommendation: "The panel recommends a skills survey and a summary of available versus needed skills, which could be used to guide hiring and transfer within CSL" (p. 202).
Laboratory Response: The Computer Systems Laboratory conducts a survey of skills when new programs are initiated and staff members are assigned to new efforts. An overall skills survey would be more beneficial when the Information Technology Laboratory is formed and its programs have been determined.
1995 Panel Comment: Although the CSL response indicates that the survey would be more beneficial when ITL programs have been determined, the panel believes that, in fact, the skills survey should be done now, since it will be helpful in the reorganization planning and in identifying skill sets that may be required in the new laboratory.

1994 Panel Recommendation: "CSL should assess the value of its 'best-in-class' examples of projects that support industrial competitiveness. These 'best-in-class' projects (with authentication by external experts) could be used as project role models and justification for future activities" (p. 202).
Laboratory Response: The Computer Systems Laboratory continues to evaluate its successful projects, to draw on the lessons learned, and to apply those insights to the design of future projects.

1994 Panel Recommendation: "CSL's formal and informal networking with industry appears to be increasing and should continue to be a priority" (p. 202).
Laboratory Response: The laboratory is pleased that its increased interactions with industry have been productive and plans to continue to work with industry in areas where it can make a difference.

1994 Panel Recommendation: "CSL needs to adopt clear and consistent metrics to monitor and assess its work. For example, CSL should categorize desktop computers used in the emerging NII [national information infrastructure] and track the extent to which CSL standards, guidelines, and other products are used in those computers" (p. 203).
Laboratory Response: The laboratory agrees on the need to monitor and assess the impact of CSL activities and will include metrics for measuring the impact of programs in the strategic plan that is being developed.

DIVISIONAL ASSESSMENTS

Applied and Computational Mathematics Division

Mission

The Applied and Computational Mathematics Division is charged with providing technical leadership within NIST in modern analytical and computational methods for solving mathematical problems of interest to U.S. industry. This work includes the development and analysis of theoretical descriptions of phenomena (mathematical modeling), the design and analysis of requisite computational methods and experiments, the transformation of these methods into efficient numerical algorithms for high-performance computers, the implementation of these methods in high-quality mathematical software, and the distribution of this software to potential clients.

Resources

Funding for fiscal year 1994 totaled $3.7 million, of which $2.8 million was from NIST Scientific and Technical Research and Services (STRS), $0.5 million was from the High-Performance Computing and Communications initiative, and $0.4 million was from other government agencies (OA). The division employs 27 full-time staff, 4 of whom are in Boulder.

The Priority-Setting Process

Most individual projects are initiated by researchers with guidance from group leaders. Many of these are joint work with other NIST laboratories; others represent the development of infrastructural technologies motivated from needs observed or anticipated after consultations with NIST researchers. Group leaders attempt to maintain a balance of projects that represent compatibility with divisional program thrusts, relevance to NIST programs, significant impact outside of NIST, and excellent science.

This year, extensive additional planning has centered on the joint efforts of the Computing and Applied Mathematics Laboratory and the Computer Systems Laboratory to define the motivation, vision, goals, and program thrusts for the Information Technology Laboratory.

Assessment of Priorities and the Priority-Setting Process

The division's priorities are defined in terms of six program thrusts developed as part of its 1994 strategic plan. These thrusts are appropriate in the context of the division's stated mission. The thrusts encompass current areas of research and identify important new areas of opportunity such as computational metrology.

The priority-setting process for project and program selection applies compatibility with the current programs as one of its principal selection criteria. This means that the interests, skills, and preferences of division staff together with program history will continue to dominate in setting the research agenda of the division. It also means that division planning tends to be short term as it is generally bound by the time horizon of the collection of currently active projects. Division management ought to engage in longer-range planning.

In view of the changing mandate for the division associated with the formation of the Information Technology Laboratory, division management needs to become more active in setting program directions that will result in appropriate changes in project content. In particular, there is a need to review regularly the thrust areas to identify and replace lower-priority thrust areas with new areas that will emphasize mathematical topics that address or enable mainstream research in information technology. Project impact, as measured by the potential customer, should play a greater role in the priority-setting process within the division.

Assessment of Technical Programs

There is a long and noteworthy tradition of research in applied and computational mathematics at NIST. Indeed, it is fair to say that much of the immediate post-World War II progress in numerical analysis and special functions came out of the National Bureau of Standards, now the National Institute of Standards and Technology. Overall, the present research program in the Applied and Computational Mathematics Division is of high quality and deals principally with materials modeling, modeling in physics and chemistry, computational geometry and metrology, image analysis, and mathematical software.

The collaboration between the Applied and Computational Mathematics Division and the Materials Science and Engineering Laboratory at NIST in materials modeling is mature and healthy. Among the joint projects are efforts in using phase field models for dendritic growth, solidification of alloys, contact lines, and isotropic-nematic interfacial instability and studies of reactive spreading of solder drops, directional solidification modeling, stochastic approaches to problems in polymer science, viscoelastic modeling of polymers near the glass transition, and elasticity and fracture of composite materials.

Following a recommendation of the 1994 Assessment Panel, the division moved to intensify its collaboration with the Materials Science and Engineering Laboratory through participation in the Center for Theoretical and Computational Material Science. Eight members of the division are participants in this center, although funding for the center has been limited.

In physics and chemistry modeling, the projects dealing with modeling of epitaxial growth, resonance and chaos in multifrequency systems, and internal waves in a viscometer near the critical point are all noteworthy. In the area of computational geometry, the work on large-scale surface representations and constrained mesh generation has made significant progress and has led to a successful collaboration with the Scientific Visualization Group within the Scientific Computing Environments Division. An important and relatively new NIST competency project on the analysis and calibration of coordinate measuring machines involves scientists from the Applied and Computational Mathematics Division, the Statistical Engineering Division, and the Manufacturing Engineering Laboratory. An analysis of the probe error in such machines has led to corrections that improve the overall measurement process.

In image analysis, there has been further progress in finding more effective deblurring techniques for positron emission tomography. This is joint work with the National Institutes of Health and should find widespread acceptance within the medical community. Other separate activities in inverse problems are also under way within the division.

The division's work in mathematical algorithms and software has achieved significant impact through the wide dissemination of the Guide to Available Mathematical Software (GAMS) The number of accesses to the GAMS World Wide Web page during the month of February reached its highest monthly total ever (8,461 hits) Public awareness of GAMS is increasing rapidly as evidenced by a recent front page story in the *Society of Industrial and Applied Mathematics News* (Vol. 27, no. 8, October 1994) announcements in *Numerical Analysis Digest*, and listings in several publications and newsletters serving users of the World Wide Web. A new project on object-oriented numerical software seeks to develop and make available reusable software components for important scientific computing applications. Iterative solutions of large linear systems and sparse matrix objects are two of the collections of algorithms implemented in C++ and made available through the World Wide Web.

The division's equipment and facilities appear to be adequate. Computer hardware is upgraded regularly, and the current shortage of laboratory space should be alleviated by the move to NIST North.

Assessment of Impact on Industry

The metrics used by division management to evaluate the industrial impact of their programs are based on the frequency of use of the division's software databases, the number of publications and citations, and the number of industry-oriented workshops organized by the division. Although it is understood that the division's impact is (currently) of an indirect nature, the assessment methodology is nonetheless nonstrategic. The division has identified six strategic thrusts, and an assessment of its impact should use criteria based on the identified thrusts.

Recommendations

The following are the panel's recommendations for the Applied and Computational Mathematics Division.

- The management of the Applied and Computational Mathematics Division should develop long-term goals for each thrust area The statement of these goals should be specific enough to guide project selection and should also serve to identify impacts on customers and define measures of success.
- Division management should regularly review and update program thrusts to identify high-priority research projects and encourage a new focus on significant mathematical topics within the information technology arena.

Applied and Computational Mathematics Division Responses to Fiscal Year 1994 Recommendations

Below are the panel's 1994 recommendations for the Applied and Computational Mathematics Division, quoted from the fiscal year 1994 report, followed by the division's response.

1994 Panel Recommendation: ". . . [Division] planning should address the fact that its goals are too ambitious for its current size and structure" (p. 241).
Division Response: Division goals are indeed ambitious. The goals are currently being revised in the context of planning for the new Information Technology Laboratory.

1994 Panel Recommendation: "The [division] should continue to emphasize the formulation of a specific team project in mathematics-based product design and manufacturing . . ." (p. 241).
Division Response: The division has begun participation in a joint CAML/Manufacturing Engineering Laboratory effort in the computational metrology of manufactured parts.

1994 Panel Recommendation: "The [division] should be proactive in communicating to NIST management the role and importance of applied and computational mathematics in NIST's interdisciplinary research programs. The division's leaders should maintain a list of accomplishments that have had a significant impact on other NIST operations or on specific industrial practices. Practical impacts should be emphasized" (p. 241)
Division Response: The division has emphasized this activity in the past year. The division chief wrote a memorandum to the NIST director describing the importance of applied and computational mathematics and the division's role in fostering interdisciplinary research. The

division hosted a laboratory visit for the NIST assistant director to provide an in-depth look at a selection of projects.

1994 Panel Recommendation: "The [division] should increase promotion and dissemination of mathematical and computational tools developed by the division" (p. 241).
Division Response: The division has emphasized this activity in the past year. The Guide to Available Mathematical Software was formally launched with overwhelming response. In early 1995, inquiries to GAMS accounted for more than one-half of all World Wide Web traffic into NIST. In addition, an anonymous FTP (file transfer protocol) site has been established to provide alternate access to this material.

1994 Panel Recommendation: "The [division] should actively promote and reward participation in the planned NIST Industry Fellows Program and use this as a means to establish direct links to industry. . . ." (p. 241).
Division Response: The Industry Fellows Program does indeed provide an excellent mechanism for establishing links to industry, and the division will continue to explore such possibilities. However, it has been difficult to motivate staff to participate and to find ideal industrial partners.

1994 Panel Recommendation: "The [division] should intensify its collaboration with MSEL [Materials Science and Engineering Laboratory] through the Distributed Center for Theory and Modeling of Materials currently being planned" (p. 242).
Division Response: The proposed center is now in operation as the Center for Theoretical and Computational Materials Science, but funding is minimal. Eight division staff members are registered participants in the center. An increase in division participation requires greater funding from the center.

Statistical Engineering Division

Introduction

Despite the uncertainty wrought by the imminent merger of the Computing and Applied Mathematics Laboratory and the Computer Systems Laboratory, by the move to NIST North, and by the lack of a permanent division director, the Statistical Engineering Division has had a productive and high-quality year. Furthermore, the staff's morale and enthusiasm for their science are remarkably high. Much of the credit for this positive situation must go to the able leadership of the acting division chief and to the division staff.

Mission

The Statistical Engineering Division seeks to catalyze scientific and industrial research through the application of statistical methods to the experimentation and data analysis underlying the empirical information gathering processes critical to NIST scientists and engineers.

Resources

Fiscal year 1994 funding for the division totaled $3.3 million. Of these funds, 80 percent came directly from STRS with the balance coming from nonbase STRS funds and NIST interdivision transfers. The division employs 25.4 full-time equivalent staff, of whom 22 are technical professionals.

The Priority-Setting Process

The Statistical Engineering Division works in areas where statistical expertise in consulting and collaborative research has the potential to contribute significantly to the NIST mission by supporting fundamental metrology, calibration and SRMs programs, outreach programs designed to transfer measurement technology to industry, and high-profile projects of national interest. The new emphasis at NIST on developing infrastructural methods that directly drive technology has led the division to expand its traditional mission to include support for the national information infrastructure via the High-Performance Computing and Communications initiative, establishment of direct relationships with industrial users, and contributions to NIST's extramural programs.

To remain on the cutting edge of research, keep abreast of important new trends, and generate a solid and credible research product, the division maintains active links with strong academic and industrial research groups. In fiscal year 1995, the division hosted nine guest researchers, two adjunct faculty, two postdoctoral researchers, and numerous invited speakers.

Assessment of Priorities and the Priority-Setting Process

The division's primary mode of operation is to respond to requests for collaboration from other NIST scientists and to mandates from Congress and the Executive Branch. Its mission statement casts the division as a service unit to the rest of the NIST enterprise, and to this extent, its priorities are influenced by those of the other laboratories. When the demand for assistance exceeds the division's ability to deliver, the directors of divisions that have multiple projects are asked to sharpen their prioritization to more effectively meet NIST needs. Although the advancement of statistical science is not explicitly included in its mission statement, the division has played and continues to play a significant role in defining and advancing such research. The Senior Research Fellowship Program, which brings in leading experts from industry and academia for extended sabbaticals, is an innovative source of input in setting priorities.

In the context of its service mission, the division's commitment of about 40 percent of its effort to the methodology of measurement science, calibration, and SRMs is appropriate in that it is fundamental to the NIST mission. The division's work adds great value to NIST's role in standards setting. In addition, the division responds promptly and appropriately to special projects mandated by Congress and by Executive Order.

Even though the division's consulting and collaboration with other NIST laboratories are funded directly by STRS, the division takes its customers seriously. Although the division has collaborated with every NIST laboratory, the distribution of collaborations is far from uniform across the institute. Generally, the choice of collaborative projects is driven by individual contacts with researchers in other laboratories. Little guidance has been provided from above, although this is not uncommon for a statistical consulting group. Notably, the one laboratory with which the division has had almost no interaction is the Computer Systems Laboratory. Opportunities for collaboration could be found in establishing metrics and standards for building and testing software and in assessing network performance.

Assessment of Technical Programs

The technical programs pursued within the Statistical Engineering Division continue to be of the highest quality. An estimated 80 percent of the work is done in collaboration with other NIST scientists and is widely distributed across the NIST laboratories. The fact that these laboratories continue to seek out collaborations with the Statistical Engineering Division is testimony to the quality of the division's work. Of particular note are examples in which division researchers have advanced the statistical contributions to these collaborations beyond the original perceived need of the collaborators. In addition to the enhancement of the specific project, such initiatives introduce the collaborating scientists from other laboratories to the power and breadth of statistics and to new (at least to them) statistical methods. In other words, these initiatives effect a transfer of statistical technology from the Statistical Engineering Division to other laboratories and divisions within NIST.

With regard to the status of equipment and facilities, a serious space shortage at Boulder threatens the division's ability to appoint faculty and fellows. This is a laboratory-level problem requiring laboratory-level intervention. The second facility concern is the impact of moving to NIST North on the spontaneity of face-to-face collaboration and consultation. The distance and parking problems, although surmountable, will discourage the easy exchange of ideas. However, the problems offer opportunities to establish a testbed for videoconferencing and other site-to-site communication technologies.

Assessment of Impact on Industry

The impact of the Statistical Engineering Division on other NIST laboratories and on industry is deep and extensive. The division's work on SRMs, calibration, and metrology adds tremendous value to NIST products. In effect, the division sets the standard for the setting of standards. The concomitant effect on industry is ubiquitous. A recent example is the development of an on-line statistics manual with integrated software for the electronics industry in collaboration with SEMATECH. The range of collaborations with other NIST laboratories that eventually lead to industrial applications is very wide.

Recommendations

The following are the panel's recommendations for the Statistical Engineering Division.

- The essential role of the Statistical Engineering Division in support of metrology, calibration, and SRMs must be maintained no matter what the ultimate structure of the Information Technology Laboratory.

- The division staff should explore opportunities for statistics in network modeling and analysis, software engineering, and other applications to information technology. The division should add staff with relevant expertise if necessary.

- Despite the excellent work of the current acting division chief, a permanent chief should be appointed as quickly as possible.

Statistical Engineering Division Responses to Fiscal Year 1994 Recommendations

Below are the panel's 1994 recommendations for the Statistical Engineering Division, quoted from the fiscal year 1994 report, followed by the division's response.

1994 Panel Recommendation: "CAML should charge an interim division chief . . . to aggressively shape the division's future in the new ITL" (p. 237).
Division Response: An acting division chief was appointed during the past year.

1994 Panel Recommendation: "The [division] should monitor its selection of projects to ensure that it focuses its effort on those most central to the NIST mission" (p. 238).
Division Response: Although the division relies primarily on informal management involvement in project selection, there is an established process that brings projects to the division.
1995 Panel Comment: A large part of the work of the division focuses on fundamental research in measurement science, calibration, SRMs, and the transfer of measurement technology, which are all technical aspects of the metrology mission. The panel commends the division on its support of this fundamental mission. The recent hiring of new staff with series expertise also reflects a responsiveness to changing priorities

1994 Panel Recommendation: "In developing a project management system, . . . the [division] should consider establishing liaison relationships organized around high-priority themes" (p. 238).
Division Response: The division has established liaisons organized around high-priority technical programs, with the exception of collaborative research that generally flows from contacts with individual scientists.
1995 Panel Comment: The division has established some specialization within the staff. For example, the traditional work in calibration and SRMs is concentrated in a few people. It has additional connections in high-performance computing and communications. However, the division continues to feel that a strong thematic substructure is incompatible with a flexible and responsive consulting organization.

1994 Panel Recommendation: "Division . . management should ensure that upper administration is regularly apprised of the division's outreach" (p. 238).

Division Response: During the past year, the division management initiated discussions on the proper role of the division with the NIST deputy director, the deputy director of the Manufacturing Engineering Laboratory, and the director of Technology Services. In addition, the NIST deputy director made two visits to the division's laboratories to learn about current projects.
1995 Panel Comment: The division has been putting more effort into communicating the breadth and depth of its contributions in the 1995 Report of Activities. On a day-to-day basis, staff have initiated several meetings with the NIST deputy director and the management of other organizations within NIST to explain their activities and contributions.

Information Technology Services

Introduction

Information Technology Services provides NIST with central scientific computing services, network and data communications, software, voice communications, administrative computing services, and related scientific and technical support. Four laboratory divisions are involved in carrying out these responsibilities: the Scientific Computing Environments Division, which is responsible for scientific visualization, user training, and software administration and support; the Computer Services Division, which is responsible for management, operation, and administration of central computing resources; the Computer Systems and Communications Division, which is responsible for central networking and telecommunications services and major systems acquisitions; and the Information Systems Division, which is responsible for administrative computing support.

The Office of the Associate Director for Computing (ADC) is responsible for the overall planning, coordination, and policy direction of the resources and operations of the NIST Scientific Computing Facility and the activities and resources associated with central scientific computing and communications services. This includes assessment of the computing needs of NIST scientific programs, assessment of current trends in information technology, planning for and installing new computer hardware, and design of software and communications strategies. The Office of the Associate Director for Computing coordinates the development and dissemination of scientific software for the high-performance computing systems component of the NIST High-Performance Computing and Communications initiative and is also responsible for network security.

Mission

The mission of those divisions that constitute Information Technology Services is to deliver the computation, communication, and information technology resources necessary to provide NIST laboratories and their collaborative partners with a strong foundation for state-of-the-art science.

Resources

The staff of the Scientific Computing Environments Division consists of 31 technical professionals and 1 administrative support person. The division's total budget for fiscal year 1994 was $2.7 million.

The staff of the Computer Services Division consists of 20 technical professionals and 1 administrative support person. The division's total budget for fiscal year 1994 was $2.9 million.

The staff of the Computer Systems and Communications Division consists of 32 technical professionals and 10 contractors. The division's total budget for fiscal year 1994 was $7.9 million.

The staff of the Information Systems Division consists of 33 technical professionals and 3 support personnel. The division's total budget for fiscal year 1994 was $2.8 million.

The Priority-Setting Process

The major priority for the Scientific Computing Environments Division is to provide central support for the current Computing and Applied Mathematics Laboratory, as well as consultation and advice for NIST users of central computing facilities. New projects are undertaken after user needs are assessed, and an effort is made to implement new technologies that add capability to NIST's computing facilities. The division occasionally receives specific direction from the office of the NIST director.

The first priority of the Computer Services Division is to ensure the availability of Central Computing Facility resources to the NIST user community. New projects are undertaken to improve existing services or to add new services and result from a continuous review process carried out in conjunction with the Office of the Associate Director for Computing.

The priorities of the Computer Systems and Communications Division revolve around the division's effort to provide reliable service and leading-edge technology. These somewhat incompatible goals are determined by its customers, some of whom want 100 percent up-time and others of whom want the latest prerelease versions of hardware and software. The division strives to balance these two goals, giving slightly greater weight to reliability.

Assessment of Priorities and the Priority-Setting Process

The Office of the Associate Director for Computing has implemented an explicit and well-defined planning process. The process includes developing annual acquisition plans for the Department of Commerce and involves significant input from its NIST customers gathered through management discussions, interaction with the Scientific Computing Planning Group, and feedback from users. The selection of priorities is based on several factors, including staff competence and an assessment of which projects would bring the greatest benefit to the largest number of users. Priorities are also greatly affected by mandates from NIST or Department of Commerce management. Such mandates can subvert the priority-setting process and often require inordinate amounts of ADC management attention.

One sign of the effectiveness of the priority-setting process is that the office can articulate examples of activities or services that it has stopped providing and examples of certain activities or services that it has explicitly chosen not to undertake. These decisions are based on customer input and resource competition. Examples of services no longer provided include terminal server and modem network support.

Although program planning appears to be effective and the selection of projects is appropriate, the ADC should consider employing more rigorous planning methods to manage those projects directed toward the development and installation of computing and communications facilities. Such projects include processor acquisitions, upgrades and installations, large-scale network design, and implementation projects such as those under way for the new buildings.

Assessment of Technical Programs

In general, Information Technology Services provides NIST scientists and staff with a high-quality computing and communication environment that is close to state of the art in most areas, including the use of asynchronous transfer mode (ATM) network technology, processor capability, visualization, parallel application support, and data storage. The development of parallel application development support tools and the transfer of this technology to industry are particularly noteworthy. The efficient manner in which the dramatic increase in networking and communication needs was met without increasing the number of staff, and the movement of the visualization technology effort from lagging to near state of the art in a relatively short period of time, are both examples of outstanding achievement.

The panel is concerned about the impact of the Commerce Administrative Management System project on the ADC. This is a large-scale, client-server application with a very large number of potential clients and is possibly global in scope. The ADC has little experience with this technology, and there is an issue with the robustness of the software. It is not clear that the ADC is adequately prepared to address the myriad issues that will arise. The project would benefit by the adoption of a client-server application development methodology, including a much more rigorous planning and testing process.

Assessment of the Impact on Industry

The Office of the Associate Director for Computing and the four divisions of the Information Technology Laboratory that together constitute Information Technology Services work primarily with other divisions and laboratories within NIST, and the industrial impact of their activities is necessarily indirect. However, ADC provides direct feedback to vendors on product direction and needs and is involved in providing review and consultation to the Advanced Technology Program (ATP). One novel area of industry interaction is software transfer to independent software vendors through the Small Business Innovative Research Grant Program. In the parallel application development area, ADC has made a concerted effort to transfer development products to non-NIST scientists through the Internet and through conference presentations.

Recommendations

The following are the panel's recommendations for the Office of the Associate Director for Computing.

- The panel urges the Office of the Associate Director for Computing to expand the use of external contractors to off-load routine services, such as PC maintenance and support, trouble-desk staffing, support of distributed servers, and support of local area networks.

- The panel recommends that the Office of the Associate Director for Computing maintain its focus on the distributed computing environment to ensure that as the technology becomes available, the ADC is in a position to implement it.

Information Technology Services Divisions Responses to Fiscal Year 1994 Recommendations

Below are the panel's 1994 recommendations for the Information Technology Services Division, quoted from the fiscal year 1994 report, followed by the division's response.

1994 Panel Recommendation: ". . . CAML staff [should] investigate the requirements for and plan a network security program" (p. 244).
Division Response: Network engineering groups in both Gaithersburg and Boulder are installing small firewalls in the laboratories in order to learn more about these systems and to better support the efforts of the Computer Security Division.
1995 Panel Comment: The laboratory has effectively responded to the recommendation of last year's panel by designing and implementing firewalls for network security.

1994 Panel Recommendation: "An allocation committee should be created consisting of representative users from across NIST charged with the responsibility of making recommendations for resource allocations based on the technical strength of proposals from the user community" (p. 244).
Division Response: A committee has been formed to oversee all aspects of the IBM SP-2 including user access. The Cray was purchased with central computing funds and is intended to be a general resource available to all NIST laboratories. The capabilities of the Cray have been upgraded such that regulation of use is not required at this time.
1995 Panel Comment: The panel predicts that the upgraded Cray will soon be saturated, and to maximize the scientific utility of the machine, some control should be exerted on its use.

1994 Panel Recommendation: "CAML should consider adding a PhD-level researcher in computational science with expertise in parallel computing to fully utilize the SP-2" (p. 244).
Division Response: The division has hired an individual with the requisite expertise to work on software for the SP-2.

Systems and Network Architecture Division

Mission

The division facilitates the development and use of networking technology through the development of networking standards, testing tools and methodologies that facilitate interoperability, and activities that demonstrate state-of-the-art technology.

Resources

Fiscal year 1994 funding for the division totaled $5.5 million. Of the total, $2.4 million are from STRS and $3.1 million from reimbursable services such as calibration services and the sale of SRMs. Division staff consists of 37 full-time-equivalent employees, of whom 27 are technical professionals.

The Priority-Setting Process

Through its interactions with industry, government, and other NIST laboratories, the division identifies areas of need and evaluates whether it has the resources and capabilities to make a unique contribution toward addressing those needs. Division management applies the following criteria to all potential projects:

- How well does the project fit the division's mission?
- What is the expected payoff to the U.S. economy?
- What level of risk is involved?
- Who are the potential partners and clients, and what is their level of commitment and/or need?

Assessment of Priorities and the Priority-Setting Process

Division management understands that the division's strengths lie in network protocols and electronic commerce and has assigned two-thirds of the technical staff to these areas. These areas are aligned with trends in information technology and industry needs. The division has a good sense of direction, but it does not have an explicit process for setting priorities. Priorities are currently established in an opportunistic rather than a strategic manner.

Assessment of Technical Programs

Division programs support network infrastructure (e.g., routing and forwarding protocols, management protocols, security protocols), result in useful applications (e.g., electronic mail, directory services, electronic commerce), and are needed to support activities not pursued sufficiently elsewhere (e.g., protocol testing and validation, performance studies).

Efforts supporting Internet protocols and work on the electronic commerce initiative are noteworthy, particularly the use of prototypes to demonstrate interoperability and integration of applications. On the other hand, the effort in formal methods is not adequately staffed to be effective.

The division is engaged in a successful program to develop improved network protocols but does not appear to coordinate its efforts with the research conducted in the Advanced Systems Division on ATM and wireless networking.

Assessment of Impact on Industry

The Electronic Commerce Integration Facility has immediate impact on industry, and expansion of this program is warranted. Both the number and breadth of collaborations are impressive. For example, 25 vendors contributed products to the electronic commerce testbed.

Recommendations

The following are the panel's recommendations for the Systems and Network Architecture Division.

- The management of the Systems and Network Architecture Division has identified the needed transition into the future, but programs require focus and a proactive plan for facilitating the transition.

- The division should coordinate its network protocol effort with the Advanced Systems Division's efforts in asynchronous transfer mode and wireless.

Systems and Network Architecture Division Responses to Fiscal Year 1994 Recommendations

Below are the panel's 1994 recommendations for the Systems and Network Architecture Division, quoted from the fiscal year 1994 report, followed by the division's response.

1994 Panel Recommendation: "The [division's] planning document should be recast in terms of the NII and electronic commerce so that the role and responsibility of the division are clear and its projects can be clearly identified with these national initiatives. The division's role in support of the ATP should also be specified in the strategic plan" (p. 219).
Division Response: The division is aware that its original strategy document is out of date. The division has decided to produce a minidocument that will later be included in a full-fledged strategy document once the reorganization of the laboratory is complete.

1994 Panel Recommendation: "Division projects on the NII and electronic commerce should focus on interoperability testing, perhaps using the Electronic Commerce Integration Facility or some similar user-perspective basis on which to test the adequacy and usability of standards and prototypes" (p. 219).
Division Response: The division has initiated work toward the development of testing materials and plans to expand this activity.

1994 Panel Recommendation: "The investigation into secure electronic mail needs to sharpen its goals and objectives" (p. 219).
Division Response: The division is negotiating a Cooperative Research and Development Agreement (CRADA) with companies that intend to build office architectures around electronic mail and directories.
1995 Panel Comment: By working with industry on a CRADA, the division will likely achieve a sharper focus with respect to its goals and objectives in the area of secure electronic mail.

1994 Panel Recommendation: "The division's mission statement needs to be analyzed, consolidated, and made more visible. The current mission statement is not useful in focusing the strategy" (p. 219).
Division Response: The division may not be able to meet this recommendation fully within the current reorganization environment.
1995 Panel Comment: The division is waiting to respond until a director for the Information Technology Laboratory is in place.

1994 Panel Recommendation: "Laboratory facilities [NIST North] must be planned so as not to disrupt the division's pending network connection, even if this means keeping the division on the main campus while other divisions move off-campus" (p. 219).
Division Response: The division is planning for the move to NIST North with a view of not only maintaining existing facilities but upgrading them as well.
1995 Panel Comment: The division has responded well to this recommendation.

Computer Security Division

Mission

The mission of the division is to enable organizations and individuals to use information technology with the assurance and trust that the confidentiality, integrity, reliability, and availability of information resources are protected.

Resources

The division has 36 full-time employees and 4 part-time employees. Guest researchers and facility members work with division staff on selected projects. Fiscal year 1995 estimated funding is $5.4 million from STRS, $1.6 million from reimbursable funds, and $186,000 from the Information Technology Services (ITS) initiative.

The Priority-Setting Process

Since it is beneficial for both government and industry to employ interoperable information technology, both the private and public sectors are considered in the priority-setting process. Priorities are set by obtaining direction and support from developers, integrators, and users who are concerned with the protection of information technology resources. Specific examples include security technology developers and vendors, private sector organizations, and government agencies. Input from these users and purveyors of information technology gathered through workshops, seminars, and collaborations is given due consideration during the priority-setting process, which involves both division management and research staff.

Assessment of Priorities and the Priority-Setting Process

The priorities and priority-setting process within the division are well developed and are in keeping with its mission statement and program management strategy. A significant change in the initiation of projects based on program thrusts has taken place. The division has begun projects within each program that capitalize on priorities, resource leverage, and outreach.

Assessment of Technical Programs

The division's focus has been adjusted to include emphasis on industry needs and direct support of NIST's internal systems. The programs emphasize enabling technologies and infrastructure projects. Attention has also been given to eliminating or obtaining external support for those areas that are resource intensive (e.g., training, management guidance, risk reviews) The five program areas—cryptography, common authentication architecture, criteria and assurance, public key infrastructure, and Internet security—directly support current information security issues and strategies.

Assessment of Impact on Industry

The focus on U.S. industry, coupled with the experience gained by the support of the implementation of security measures within the NIST systems, ensures that the overall program will have a substantial impact on industry. The following projects are of significant impact:

- The Validation Program and the transfer of validation activities to commercial laboratories;
- The work with private and government sectors on Cryptographic Application Program interfaces;
- Development of a high-level framework and supporting standards to improve interoperability of authentication technologies and services;

- Establishment of CRADAs with industry to address public key infrastructure interoperability issues;
- Support for the Advanced Systems Division in wireless transmission errors with respect to encrypted data;
- Development of Internet security tools, policy guidance, security administration, and security plan; and
- Completion of the common criteria and investigation of alternative assurance approaches to current evaluation methods.

Recommendation

The following is the panel's recommendation for the Computer Security Division.

- Nine specific measures of success have been established by the Computer Security Division to reflect the expected results of a successful information security program. However, metrics for each of the nine measures should be established to adequately gauge their status. An annual summary of these metrics should be formally reported. Also, at that time, an internal assessment of the effectiveness of each of the metrics should be conducted and adjustments made accordingly.

Computer Security Division Responses to Fiscal Year 1994 Recommendations

Below are the panel's 1994 recommendations for the Computer Security Division, quoted from the fiscal year 1994 report, followed by the division's response.

1994 Panel Recommendation: "The [division] should develop a crisper and more complete strategy statement to support [its] mission, which should also be consistently stated in all strategic planning documents and presentations" (p. 216).
Division Response: The division has developed a specific strategic goals statement as part of the Information Technology Laboratory planning effort.

1994 Panel Recommendation: "The [division] should use program plans to track progress and deliverables" (p. 216).
Division Response: The division has developed program and project plans for all major activities; they are used to monitor the work.

1994 Panel Recommendation: "The division should consider assigning and *increasing* resources to programs having broad-based applicability, such as distributed authentication and Internet firewalls" (p. 216).
Division Response: The division is currently focusing special efforts on both distributed authentication and Internet firewalls, along with a range of other related Internet security work.
1995 Panel Comment: The Computer Security Division's 1995 planning document indicates close attention to the 1994 recommendations. With only a slight deviation (virus prevention and

detection), all 1994 recommendations have been addressed and positive actions have been taken Of particular note is the division's attention to project management and tracking of actual versus planned deliverable dates for milestones.

Systems and Software Technology Division

Mission

The mission of the Systems and Software Technology Division is to support users and industry through promotion and evolution of open systems concepts and technology, quality software development and integration, software engineering concepts, document concepts and technology, and heterogeneous distributed systems concepts and technology.

Resources

The division has 38 full-time employees. Of the $4.5 million in total funding for fiscal year 1994, $2.5 million was from STRS, $1.9 million from OA and reimbursable services, and $0.8 million from the ITS initiative.

The Priority-Setting Process

Program priorities are established by assessing a composite set of issues articulated by collaborating federal agencies and by participants attending division-sponsored forums and workshops User technology integration requirements and technical barriers to computer system interoperability are compiled into a program of work The highest priority is given to solutions that integrate various disparate technologies at a system interface (human, data, communication, and application).

Assessment of Priorities and the Priority-Setting Process

The division has made significant progress in the area of articulation of priorities. Discussion with the division staff makes clear that projects are selected in accord with the needs of industry and the mission of the division. The process by which these priorities are set is still less visible and explicit than might be desired, and the staff are encouraged to continue to work on the process of making this priority setting more formal.

The division's mission is appropriately broad given the rapidity of change in this area. The division is made up of three groups: Software Engineering, Distributed Systems Engineering, and Office Systems Engineering. Although software engineering is an established area of study, distributed systems engineering is less well defined, and office systems engineering is a new field. Thus, the groups are working at differing levels of definition and clarity. The approach of exploring new technologies as they emerge seems to be working well. In particular, the work in object technology, portable documents, web documents, and health care infrastructure is consistent with the mission.

The division is working with the Information Systems Engineering Division to begin the process of planning for the formation of the Information Technology Laboratory. The two divisions have developed specific plans for how they might contribute to both application engineering and interoperability within the structure of the new laboratory. The current state of the planning process is appropriate, and the staff are positively engaged in the redefinition of their division's mission. Division staff exhibit a refreshingly positive approach to the challenges and opportunities posed by the creation of the new laboratory.

Assessment of Technical Programs

The quality and effectiveness of the technical programs pursued within the division are strong but could possibly be improved further by focusing on fewer projects with larger collaborative groups.

With regard to the status of the equipment and facilities, a high-technology area has a continual need for upgrading and enhancing the computer environment, local workstations, and communications and a need for more powerful shared facilities. In particular, the future development of the Virtual Reality Testbed will require more investment and should be carefully coordinated with divisions doing related work, e.g., the Visualization Group in the Computing and Applied Mathematics Laboratory and the Advanced Systems Division.

Assessment of the Impact on Industry

Many projects have developed effective connections with the standards community and the other laboratory groups. The pace of development in both the health care and object technology fields is rapid; these areas require more resources and emphasis if the division is to make a significant contribution. The virtual reality field is quite fragmented, and division activities directed toward establishing standards and protocols should yield immediate benefit.

The impact on industry of division programs is difficult to measure. The priorities being set for the National Information Infrastructure initiative may represent one framework within which division activities might be assessed and tracked. The panel was impressed with the specific anecdotal evidence provided by the staff regarding the industrial impact of division programs.

The Health Care initiative, the High-Integrity Software System Assurance (HISSA) project, the Integrated Software Engineering Environment project, and research on virtual reality development are important, high-visibility projects. Further, the ability to effectively influence technology development in these areas will vary broadly with health care being the most problematic. Health care has a broad collection of different organizations, including medical societies and other federal agencies, that control and issue requirements, specifications, and standards. Currently, NIST has no presence in the medical community and may have difficulty in promoting its viewpoint.

Recommendation

The following is the panel's recommendation for the Systems and Software Technology Division.

- The Systems and Software Technology Division should find a way to establish credibility within the medical community for its contributions to the Health Care initiative.

Systems and Software Technology Division Responses to Fiscal Year 1994 Recommendations

Below are the panel's 1994 recommendations for the Systems and Software Technology Division, quoted from the fiscal year 1994 report, and the division's response.

1994 Panel Recommendation: "The Systems and Software Technology Division should revisit its objectives and strategy statements and revise them to define more focused and achievable goals" (p. 212).
Division Response: The division is doing this in the context of the goals and objectives established for the Information Technology Laboratory.

1994 Panel Recommendation: "The division should examine development processes and develop specifications for safety-critical software development processes" (p. 212).
Division Response: The division is following this advice in the HISSA project and has developed a framework for the development and assurance of high-integrity software describing SRMs.

1994 Panel Recommendation: "The division should give attention to standards for process engineering" (p. 212).
Division Response: The division is heavily involved in this activity.

1994 Panel Recommendation: "The Virtual Library project should work with industry to establish a set of requirements and specifications to support universal electronic document exchange" (p. 213).
Division Response: The division has engaged in an active program involving a series of workshops and a government blue ribbon panel. Results will be published shortly.

1994 Panel Recommendation: "The division should take a more active role in the SEI [Software Engineering Institute] capability maturity model, developing a program with SEI and taking a leadership role in mapping the CMM [coordinate measuring machine] to the Generic Life Cycle Model" (p. 213).
Division Response: The division is following this advice in the HISSA project.

Advanced Systems Division

Mission

The Advanced Systems Division develops commercial enablers for advanced information technologies likely to lead to large new markets and facilitate the development of the national information infrastructure. These enablers are cooperatively agreed-upon reference materials, tests, and instruments that provide measurement methods necessary to drive research prototypes into a commercial paradigm or demonstrate the commercial methods of two or more competing research paradigms.

Resources

The division staff includes 91 full-time-equivalent employees. Funding for fiscal year 1994 totaled $9.2 million consisting of $3.3 million from STRS, $4.6 million from OA, $0.7 million from NIST competence funds, and $0.6 million from the Information Technology Services initiative.

The Priority-Setting Process

The division's activity focuses on the convergence of computation, communication, and display technology. Within this framework, the division has chosen to concentrate on the development of measurement methods for three key advanced technology areas: human-machine interfaces, digital communication (broad-band integrated services digital networks and wireless), and advanced technology platforms (parallel processing, optical storage, and flat panel displays). The division is working with industry, academic researchers, and users through workshops and collaborations to direct its efforts toward the needs of its customers.

Assessment of Priorities and the Priority-Setting Processes

The division's process of actively interfacing with industry, using high levels of other agency funding and informal methods to find the leading technological edge, is adequate in the absence of a driving vision from upper management.

The division's activities in human-machine interfacing, advanced component technology, and high-capacity networking represent a reasonable view of where the information processing industry is going. Similarly, the division's interaction with industry through its generation of corpora and other test materials is helpful. The division's efforts in the development of holographic memory and three-dimensional display are well warranted. Understandably, the selection of specific projects depends on client interest. However, this tendency must be tempered with a strong commitment to strategic objectives.

Assessment of Technical Programs

The overall quality of the division's programs is very high, but there is still some room for improvement. The laboratory's leadership is dynamic, and overall researcher morale appears to be good; there is considerable enthusiasm for existing projects, and staff members appear satisfied that they are working at the leading edge of technological development. The entrepreneurial organization of the division leads to a strong, results-oriented program. Milestones are taken seriously, and continued high levels of sponsor support suggest that, by and large, the milestones are being met.

The panel reviewed the division in terms of its three program categories: human-machine interface, advanced components, and networking. The emphasis on the human-machine interface has, as its primary goal, the production of corpora (databases against which various algorithms are tested). These corpora appear to be well received, and the division, in the production and analysis of these corpora, has played a useful role in fostering synergistic cooperation within the wider research community. That said, it is not clear that the production of corpora is as technologically demanding as might be suggested by the quality and quantity of personnel. Understandably, their production is necessary, and to be a credible member of the community in which the corpora are circulated requires considerable technological depth. It should be possible to devote some of that technical capability to other research projects even if they are not metrology outputs per se.

The advanced components projects are technically excellent but require greater attention to relevance and timely delivery. For example, the research on flat panel displays and CD-ROMs has been valuable, but both programs should already have been packaged and delivered to industry. Transfer of these projects to industry would permit the devotion of greater resources to three-dimensional storage and display technologies. Parallel processing work seems to suffer from a lack of relevance: the MultiKron project was a technical success but has not yet been successfully transferred to industry, and the S-check approach taken by the parallel computing program to metrology is not compatible with the approach industry has taken.

The division has a contribution to make in developing metrology for parallel systems; it seems to have shied away from this task because of past problems over export controls and current controversies over possible bias among vendors. Yet the federal government, as the mainstay of the parallel processing industry, has a strong and continuing need for such metrology, and the division ought to find a way to fill this need. The division maintains a node on the Beltway Bitway and has played a leading role in developing simulators for testing ATM congestion control schemes. The division should more actively define how it will use its Bitway node (inter-NIST applications are insufficient justification for such activity).

With regard to the status of equipment and facilities, the panel perceived no evidence of any inadequacies.

With regard to data programs, the division has achieved merited industry respect in its development of numerous corpora covering test areas in speech recognition, handwriting recognition, natural language processing, and facial recognition, among others. Standards per se are not a focus of division effort, but the division has nonetheless made contributions in several areas, particularly in networking.

In view of the division's manifest technological strengths, the panel believes that the division could do much more, especially in image and other compression, in fundamental research affecting the development of a consistent semantic substructure for NII communications, and in problems that may detract from the scalability of large networks.

Assessment of Impact on Industry

Because one-half of the division's budget comes from other agencies, a large share of its activity furthers the mission of other parts of the government (e.g., face recognition for the Federal Bureau of Investigation and handwriting recognition for the Internal Revenue Service). The division has several methods of assessing the impact of its work on industry. One method is its success in the standards arena: the division participates in the ATM Forum and in other areas (e.g., in library retrieval systems). Another method is the degree to which it has been able to attract industry to its symposia and other forums or attract participants to its CRADA. A third is the degree to which its published outputs (e.g., printed material, corpora on CD-ROM) are requested by others.

The division's impact on industry is growing, but it remains modest, particularly given an annual budget of over $9 million. Many of its programs are driven by researcher interests rather than industry relevance. The division's methods for determining how well it is doing, however, are more than adequate.

Recommendations

The panel recognizes that the formation of the Information Technology Laboratory and the appointment of a new director will lead to new thinking about the overall role and mission of what is now the Computer Systems Laboratory and its constituent divisions. Although the precise nature of the new guidance cannot be known with certainty, it is likely that it will accentuate the role that NIST will play in enabling the NII, notably through advances in interoperability, the human-machine interface, and scalability. The panel's recommendations, accordingly, are as follows:

- The Advanced Systems Division should continue to devote an increasing share of its resources to fostering interoperability, particularly in the area of human-computer interfaces, video and other forms of compression (e.g., in support of wireless communications), and complex networks. The Advanced Systems Division, together with other divisions, should begin work on developing semantic substructures for national information infrastructure communications, particularly at the middleware layer.

- The division should convert the technical work it does as a prerequisite to generating corpora into other research products with discrete deliverables.

- The division should find a sponsor for whom it can develop benchmark algorithms for parallel processing machines; this sponsor should be expected to take ownership of these benchmark algorithms.

- The division should continue to pursue outside funding. However, funding alone is not evidence of relevance to the NIST mission. Project selection must pay more attention to the overall NIST mission and to the mission of the Information Technology Laboratory. Similarly, it is good when investigators' interests can be accommodated within the confines of the mission and vision, but investigator interests should be a second-order effect.

Advanced Systems Division Responses to Fiscal Year 1994 Recommendations

Below are the panel's 1994 recommendations for the Advanced Systems Division, quoted from the fiscal year 1994 report, followed by the division's response.

1994 Panel Recommendation: "The [division] needs a baseline architecture or comprehensive model on which to relate the various division projects. . . ." (p. 223).
Division Response: The division has concentrated its efforts under the three general headings of human-machine interfaces, digital communications technology, and advanced technology platforms, focusing on instrumentation, evaluation, test corpora, and interoperability in each area This provides a baseline and some projection into the future for planning purposes.

1994 Panel Recommendation: ". . . [More] work . . . should be oriented toward interoperability issues and toward developing standards derived from [those issues] . . ." (p. 224).
Division Response: The division's work on flat panel displays, optical computing, Z39.50, network protocols, and future digital video deals with interoperability and portability issues.

1994 Panel Recommendation: "The division should carefully plan to minimize disruption by the planned move to off-campus space" (p. 224).
Division Response: The Advanced Systems Division will remain on the main NIST campus in Gaithersburg.

1994 Panel Recommendation: "The division should consider development of computer languages for controlling new machine architectures" (p. 224).
Division Response: The opportunity to pursue this avenue has not yet arisen.

1994 Panel Recommendation: "The division should consider more beginning-to-end testing processes based on user scenarios to avoid oversights resulting from testing a technology without a user community perspective" (p. 224).
Division Response: The division is beginning this type of effort with the prototype natural language interface for libraries. The division plans further work of this type as the opportunity arises as part of the focus on human-machine interfaces.

1994 Panel Recommendation: "Projects are dropped when they are deemed ready for maintenance. . . . The [division's] transition process should be better defined and documented" (p. 224).

Division Response: The division effects a transition to new projects when the technologies in an existing project have been accepted in the marketplace and no longer benefit from NIST resources.
1995 Panel Comment: The panel recognizes the limitations of fixed objective criteria for project transition, but it urges that transitions in some cases (e.g., MultiKron, and CD-ROM archiving metrology) be accelerated.

1994 Panel Recommendation: "The [division] should consider additional work in several interoperability areas . . . (p. 224).
Division Response: The division is planning work in the digital video area by establishing a testbed for investigating interoperability issues.

Information Systems Engineering Division

Mission

The division conducts research, development, and technology transfer to industry. The division delivers products and services such as profiles and guidelines, prototypes and reference implementations, tests and demonstrations of feasibility and interoperability, and conformance tests and certification that software products conform to standards. The division provides direct assistance to industry and local, state, and federal government agencies.

Resources

Division staff include 39 full-time employees and 4 part-time employees. Funding for fiscal year 1994 totaled $5.1 million, including $2.2 million from STRS, $2.7 million from OA, and $0.2 million from NIST competence funds.

The Priority-Setting Process

The division obtains direction and support from industry (primarily information technology developers, integrators, and users), academia, and government through workshops, demonstration projects, and cooperative agreements. Progress is measured in terms of products and services delivered and the degree to which those products and services are accepted in the marketplace.

Assessment of Priorities and the Priority-Setting Process

The priorities of the division appear to be appropriate and well balanced. However, an explicit process for establishing priorities is not apparent. The division focuses on the development of enabling technologies and is closely connected with its customers. Planning for new activities tends to be opportunistic rather than strategic.

Assessment of Technical Programs

The quality and effectiveness of the division's technical programs are very high. However, the division may be holding onto programs too long. Some current projects could logically be turned over to industry. In terms of generating new ideas to lead the industry, the division hosts visiting scientists and works with industrial researchers, on both a national and international level. However, many of the staff are from traditional data management backgrounds, and a systematic retraining and education program should be established to ensure that the division maintains a leadership role in changing the data management environment.

Facilities required to support the development of virtual reality technology appear to be limited. Video conferencing facilities need to be enhanced and may require additional space.

Assessment of Impact on Industry

Projects pursued within the division have generated a great deal of interest on the part of industry. The division's Center for Applied Information Technology serves as a focal point for its interactions with industrial users. Division support of the database language SQL and development of test suites are of immediate benefit to industry.

Recommendations

The following are the panel's recommendations for the Information Systems Engineering Division.

- The Information Systems Engineering Division should hasten the process by which projects are handed off to the user community.
- The division should ensure that current staff engaged in research related to data management technology maintain state-of-the-art expertise.
- The division should consider making improvements in video conferencing and virtual reality facilities as resources allow.

Information Systems Engineering Division Responses to Fiscal Year 1994 Recommendations

Below are the panel's 1994 recommendations for the Information Systems Engineering Division, quoted from the fiscal year 1994 report, followed by the division's response.

1994 Panel Recommendation: "The [division] needs to find ways to off-load conformance testing to outside sources" (p. 207)

Division Response: Outside sources are being used for developing conformance tests, for conducting testing, and for administering the testing programs.

1994 Panel Recommendation: "The Graphic Software Group . . . should expand its scope to include PC workstation graphical user interfaces" (p. 207).
Division Response: The group's scope already includes this activity.

1994 Panel Recommendation: "The [division] must clarify and better coordinate its joint program on virtual reality with the Systems and Software Technology Division" (p. 207).
Division Response: The division is working with the Systems and Software Technology Division on a joint project, Systems Integration for Manufacturing Applications, utilizing virtual reality technology.

1994 Panel Recommendation: "The division must plan more explicitly, including planning for new technology areas. It seems to emphasize support for its ongoing activities rather than support for new research activities" (p. 208).
Division Response: The division engages in new activities when those activities are requested by industry. Such requests are often in the context of ongoing activities, which biases the division's projects in that direction.

1994 Panel Recommendation: "The division should take an active role in software reuse technologies" (p. 208).
Division Response: The division is interested in assuming an active role, but a lack of funding has limited the division's efforts.

1994 Panel Recommendation: "The division should study automatic testing methods for software standards" (p. 208).
Division Response: Automatic testing methods are used whenever possible, but there are limitations imposed by the nature of the test suites available or by the nature of the testing itself. The division is currently studying two automatic testing methods that automatically generate code from detailed specifications. The division plans to use one of these methods to develop conformance tests for a new image processing standard

1994 Panel Recommendation: "The division should use the Computer Security Division's strategic plan as a model for its own planning" (p. 208).
Division Response: The division has adopted the recommendation.

1994 Panel Recommendation: "The division should revisit the panel's fiscal year 1993 recommendation on conformance tests" (p. 208).
Division Response: This issue has been revisited and will continue to receive attention.

Mrs. MORELLA. Thank you, Dr. Roskies.

Dr. Brownstein?

STATEMENT OF DR. CHARLES N. BROWNSTEIN

Dr. BROWNSTEIN. Mrs. Chairwoman, Ms. McCarthy, thank you for the opportunity to testify today. I am the Executive Director of the Cross-Industry Working Team which represents 45 of our leading information technology and service companies. I will leave you with some of our public materials about the future of our information infrastructure for your Committee's use.

I bring some additional perspective as a member of the Public Policy Committee of the ACM and from time spent at the National Science Foundation, where, among other things, I managed the Directorate for Computer and Information Science for a while and worked fairly closely with NIST.

I am most pleased to be here, however, as a resident of Maryland's 8th Congressional district. I'd like to thank you for getting our lights turned on.

[Laughter.]

Dr. BROWNSTEIN. I provided written testimony for the record, and so I'd just like to make a few comments to highlight what our members told me when I asked them about the role and utility of NIST's information technology activities.

I think I would associate, first, myself and the XIWT with the opening statements. Few issues affect our economic health as those which affect our information industries and the goods and services which they enable. Given the critical place of Federal investments in the evolution of this industry, your Committee's understanding and actions will affect every American profoundly.

It's well documented that what are popularly misunderstood as revolutions in this field are the product of knowledge and human resources generated by the longstanding partnership of the government, industry, and the academic community. Fundamental technology and applications research is the cradle of much of the visible entrepreneurial activity that brings products to market.

It's less well documented and scarcely understood outside of industry that the efficient extension of these technologies to mass deployment is dependent on a reasoned degree of consensus, agreement, and common ground, and that's why industry values NIST as a competent, neutral asset in the competitive exchange of information technology arena.

XIWT member companies believe that the Information Technology Laboratory has made important contributions by its support of industry's voluntary standards development processes and in facilitating some particularly difficult areas of fundamental research, and that it should continue to do so in the future. In particular, XIWT member companies believe that NIST should promote marketplace solutions to the selection of standards. We believe the desired course of government is to avoid intervention through the promotion or legislation of particular technical standards, however.

ITL should also support the voluntary industry standards process by offering its expertise in metrology to assist the understanding of complex alternative. Industry needs the ability to select technical standards by its own processes. We are in an era of continuous improvement in the underlying technologies for information processing and communications. An abundance of new and competing solutions to information processing and communications requirements have resulted from our public investment in research and education over the past several generations.

Government has a role in facilitating the process of achieving industry consensus by providing vendor neutral methods for performance assessment, the independent trusted data about performance, and neutral forums for the consideration of contending issues. That is not to say that NIST should create or support such forums. Industry has the resources and incentives to do that.

But where invited, NIST can provide a useful neutral participant role, particularly early in the process of considering standards, subsequently where there is a clear industry consensus about the need and a willingness to collectively provide direct support for such activities. There is a balance that has to be achieved about competing priorities and it is incumbent on NIST to work with industry to assess priorities but then to make the hard choices that competing interests would always generate.

Third, NIST should contribute to the U.S. Government position in international standards activities, helping government share this burden with industry, since the management of standards has strategic trade implications. Industry may not easily aggregate its own interests and our European and Asian trading partners strategically fund both government and industry involvement.

Finally, NIST should participate with other agencies in the support of fundamental research, using its special expertise in standardized testing and performance evaluation, as appropriate. Government has a very important role to play in the generation of new fundamental knowledge that all of society can exploit. Most of this responsibility and the bulk of public resources are in other agencies, such as the National Science Foundation and DARPA, which together support 60 to 75 percent of all academically-based fundamental research and information technology.

These agencies specialize in forefront risky cutting-edge research and development in technology and applications and usually have little patience to follow up with some of the more critical work that needs to be done to support even research activities over the long run. NIST's Information Technology Laboratory thus compliments these agencies in important and difficult technical areas in which standard test suites and performance evaluation methods and criteria facilitate technology improvements that all of industry can exploit. The laboratory's intramural research and open scholarly publication in selected areas is also essential to maintaining its own staff capability and credibility in this area.

Thank you very much. I'll be pleased to respond to any questions.

[The prepared statement of Dr. Brownstein follows:]

Testimony of
Dr. Charles N. Brownstein
Executive Director, Cross-Industry Working Team
Corporation for National Research Initiatives

U.S. House of Representatives Committee on Science
Subcommittee on Technology
April 29, 1996

Mrs. Chairman and members of the Subcommittee, thank you for the opportunity to testify on technical and policy issues facing the information industry and the role of the Information Technology Laboratory of the National Institutes of Standards and Technology in dealing with these issues. My name is Charles Brownstein. I am the Executive Director of the Cross-Industry Working Team (XIWT), a coalition of 45 leading companies in the information services, communications and computing industry, which are working together to accelerate the development of the national information infrastructure. This position brings me into continual contact with the technical, business and public policy issues affecting many of our leading, most innovative information technology companies.

I bring additional perspective as a member of the Public Policy committee of the Association for Computing Machinery (ACM), and from my background as a Trustee of the Internet Society, the capstone organization for Internet standards; and from service at the National Science Foundation, where, in various capacities from 1985 to 1991, I managed the Directorate for Computer and Information Science and Engineering, and chaired or participated in many interagency committees and cross-sector activities which involved the people and capabilities of the laboratories which are the subject of these hearings.

Background

America's information industries and the progress they make in deploying the broad set of information technologies that fit under their rubric of "national information infrastructure," have had, and will continue to have, substantial leverage on every aspect of our economic and social well being, national competitiveness and security. Commerce of every sort, government performance, health care, education, publishing, scientific and engineering research, entertainment, national defense, law enforcement, politics and our personal communications capabilities are all profoundly affected today by advances in information technologies and the applications they enable.

In the practical near term and over the long run, few issues affect the future economic health facing the nation as those affecting our information industries and the cascade of goods and services which they enable. With the recent changes in the laws, the astringent forces of competition, and the likely future decline in knowledge generating capacity due to financial pressures on both government and industry, the Congress' comprehension of the issues we discuss today will affect every American profoundly in the future.

American industry is noted for information technology "revolutions" such as converge today in the Internet— computers, telecommunications, and user friendly multimedia applications. It is very well documented that these revolutions are a product of the knowledge and human resources generated by the long standing partnership of the federal government, industry and the academic comity in fundamental technology and applications research, and the subsequent entrepreneurial activity of our economic system. It is less well documented and scarcely understood outside of industry, that the efficient extension of these technologies to mass deployment, where they are brought to bear on everyone's lives, is dependent on a reasoned degree of consensus, agreement, and common ground.

All of which, perhaps, explains why industry values the presence of NIST as a competent neutral party, and views it as a national asset in the competitive, changeable information technology arena. XIWT member companies believe that NIST's Information Technology Laboratory has made important contributions to the advance of technology and the health of our industry by its efforts to support industry's standards development process and in facilitating the conduct of some particularly difficult areas of fundamental research, and should continue to do so in the future.

Issues Facing America's Information Technology Industry

There are many kinds of issues facing our information industries. Some involve technology in various application domains- such as commerce, health care, entertainment content; others involve enabling technologies and services, such as security or intellectual property rights management; still others involve the interoperability of particular systems, such as applications software or telecommunications services. Continual technology and marketplace evolution makes these continual issues, best dealt with by technical experts. History tells us that they can be readily dealt with on a continuing basis, *if* some larger issues involving the interplay of public policy and technology are understood. Thus my testimony is focused on four key issues.

First and foremost, is the issue of government intervention in the marketplace. The industry needs the freedom to compete. Recent changes in the laws are designed to promote competition in order to drive down prices and drive up innovation by providing more choice to consumers. The changes can succeed to meet these goals if industry is able to operate in open free markets, to offer innovative products in every domain of interest to consumers, and to permit consumers to determine which products and services have value. Government has a legitimate role in ensuring that markets are open, and in being vigilant against actions of the public or private sector, which foreclose the ability to offer service and product innovations to consumers. We thus believe that the desired course of government is to avoid intervention, particularly to avoid the promotion or legislation of particular technical standards.

Second, industry needs the ability to select technical standards by its own processes. We are in an era of continuous improvement in the underlying technologies for information processing and communications. We are reaping the seeds sown in our public investment in research and education over the past several generations, in the form of an abundance of new and competing solutions to information processing and communications requirements. To employ these solutions most effectively and efficiently, industry needs the ability to work within the competitive environment, to achieve the degree of consensus that permits widespread deployment of technology and systems. Government has a role in facilitating the processes of achieving industry consensus by providing vender neutral methods for performance assessment, independent trusted data about performance, neutral forums for the consideration of contending issues, and by stimulating institutions for continual assessment and assurance of performance for the marketplace.

With respect to both technology and its application, such consensus may deal with engineering and business practices, with performance characteristics of components or systems, or with specifications for the makeup of components and operations. These can be achieved most effectively where contending ideas, technologies, people and companies share the common ground of broad agreement on the architecture— the overall plan for systems and the rules that bind them together. Subsidiary agreements on standards cap very human processes of generating common understandings. There is, however, no simple "right" process which actually determines standards in a truly open, competitive marketplace. The lack of a process may do it: a dominant vendor sometimes sets a standard, de facto, by monopoly power. Or, groups of vendors may simply jointly settle on a particular standard to gain market position. Or, engineers may propose ideal solutions which attract the attention of vendors to build within a proposed framework. Similarly, there is no single way to get to the "best" standard, nor any guarantee that any particular standard will be worth keeping in the face of opportunity created by innovation.

Nonetheless, industry and consumers value standards, and in practice, industry the world over engages in voluntary, industry-led forums to work together to agree on fundamentals and on specifications which they publish openly for participants to use in the design of products. Standards may reduce uncertainty about what to build and sell, may assure that parts and systems from diverse manufacturers will work together, may generate economies of scale, allowing a large number of a product to be created because of the likelihood that there will be market acceptance based on confidence that parts and systems will perform as advertised. Standards may be important to consumers as well. If there are multiple providers of interchangeable devices, competition reduces prices. If devices and systems interoperate effectively, the reach and utility of networks expands for everyone as the market grows.

One of the keys to the advancement of technology in the US, and the success of US companies in other markets, has been the wide acceptance of standards developed in open forums, and in the power of the marketplace rather than fiat, to weed out inferior products. Both industry and the consumer make good use of information about performance in making their choices. Generating confidence in technology performance requires defining acceptable metrics of performance and of verification of facts. A neutral participant, one that is independent of particular vendors participating in the deliberative process of voluntary industry standards organizations is needed to: provide standardized test procedures; administer system benchmark tests, certify that adequate testing has occurred, and facilitate the efficient resolution of engineering disputes. Practical issues involve getting common performance test parameters and measures, designing standard methodologies, and providing the benchmarking data.

This is not to say that NIST should attempt to provide forums: industry has the resources and the incentives to do that. In some areas, NIST has been invited to provide a critical neutral "host" role which has allowed all segments of industry to have a fair hearing. In some areas, NIST- assisted forums have facilitated the interaction of vendors and consumers early in the process of considering standards. The importance of this neutrality will grow as cross-industry competition increases in the wake of changing telecommunications laws. Should NIST step down from the roles it has evolved, other less "vendor-neutral" coordinators may step forward, and the benefits of open competition in open markets may be lost.

My third issue involves international competition. America's information industry is thriving on open global competition. It can continue to do so only with adequate representation in international governmental deliberations about standards. Foreign governments may specify requirements (e.g., conformance, certification) concerning the sale of products or services within their countries (even though such requirements often add to the cost of and slow the development and deployment of new information infrastructure products and services). These governments may also require that negotiations on how to meet these requirements be carried out between governments, rather than by voluntary industry bodies. In such cases, the U.S. needs a technically competent governmental representation and a channel for U.S. industry to participate in such negotiations. The Information Technology Laboratory can play an important role by providing technical support to both government and industry.

Fourth and finally is the issue of sustaining knowledge resources for the future. With improved competition, industry is driven to deal ever more intensely with "bottom line" considerations of consumer acceptance, cash flow, and the pressures of profitability, at the expense of long term knowledge and man resource considerations. Industry needs a continuing supply of new knowledge and new human resources, which is beyond its capacity or direct economic interest to create. The government has an important role to play in the generation of new fundamental knowledge which all of society may exploit.

Most of this responsibility, and the bulk of public resources is in agencies such as the National Science Foundation and DARPA, which together support from 60- 75% of academically based fundamental research in information technologies. These agencies (and others with nationally critical missions such as health, national security, and space) invest in forefront, risky, cutting edge research and development in technology and applications. NIST's Information Technology Laboratory is an important component of this well proven knowledge generation system. It provides a suitable venue for long term inter-sector collaboration in several interesting and difficult technical areas in which standard test suites and performance evaluation methods and criteria facilitate technology improvements that all of industry can exploit. The Laboratory's intramural research, and open scholarly publication in selected areas is essential to maintaining capability in this arena.

In summary, NIST's Information Technology Laboratory should:
1) promote marketplace solutions to the selection of standards;
2) support the voluntary industry standards process, particularly by offering it's expertise in metrology to assist the understanding of competing alternatives;
3) contribute to the US position in international standards activities; Government should share this burden with industry since the management of standards has strategic trade implications. Industry may not easily aggregate its interests, and our European and Asian trading partners presently fund both government and industry involvement.
4) participate with other agencies of government in the support of fundamental research, using its special expertise in standardized testing and performance evaluation as appropriate.

Addendum

Industry Comments on the Value of the NIST Information Technology Laboratory

-Telecommunications
"As you may already be aware, that 802.14 is a key enabling residential broadband technology that leverages the ubiquitous cable TV infrastructure taking decades and billions to build.

To provide affordable high speed internet access (and other multimedia applications) for consumers and small businesses, infrastructure and networking products (such as cable modems) must be based on open standards. IEEE Project 802.14, has provided a structure for world-wide participation to define a best-in-class access method and transmission standard (MAC/PHY layers) so that interoperative products can be based.

(NIST's) group has participated and contributed to the evaluation of MAC (medium access control) proposals from competing participants. NIST's role as a neutral party has been, and will be increasingly important for the group to converge to a standard in a timely fashion.

We would very much like to see (NIST) continue work on the Common Simulation Platform to facilitate the selection of protocol features based on technical merits and to ensure future interoperativity of implementations based on 802.14.

We need the continuity of the work being started (NIST) to ensure a robust and deployable standard."
(Digital Equipment Corporation)

" Examples of Positive Partnerships (past/present actions): 1) Support of a single national standards on-line network (NSSN) - NIST positive and pursued activity even though ANSI was (at first) hesitant 2) Support of PAS (publicly available specifications) RS (reference specification) positions/documents in JTC 1, participate in standards meetings, facilitate dialogs with potential PAS providers 3) Participate and bring in global perspectives of voluntary testing and certification to the North American Interoperability Policy Council; convey North American policies to other national government agencies 4) Involved in and supportive of US industry activities to promote the GII such as the Information Infrastructure Standards Panel; led activity to develop a common framework, provided tutorials to promote the framework, sponsored health care activity to identify the standards that will be required for that industry."
(HP)

" - NIST has had active and contributing participation in major information technology standards development organizations such as the Accredited Standards Committee X3 and the associated JTC 1 TAG. We have observed the NIST members assume roles in sub-committee work and international delegations to promote national views on critical technical and policy matters.

- The Information Infrastructure Standards Panel(IISP), an ANSI sponsored organization chartered to identify requirements for standards that will be needed to develop the NII/GII, has benefited from NIST participants. In particular, one NIST individual was responsible for leading the development of a three dimensional framework now being used by the organization as a guide for this requirement identification. Of note, this individual has also been instrumental in working with subgroups on the use of the framework which has led to numerous quality outputs.

- In the IISP context, another NIST participant has been heavily involved in coordinating the use of the framework with the national efforts on healthcare informatics. This activity is the most complex to date and the NIST individual has been coordinating most effectively between the IISP and the person who is the Executive Director of the Medical Records Institute, ANSI HISB (ANSI Healthcare Informatics Standards Board).

In summary, Apple's experiences with NIST participation in these various venues has been positive. The individuals we have worked with have been knowledgeable, cooperative, and effective contributors. "
(Apple Computer)

" At the ANSI T1A1 meetings which develop telecommunications standards they have been hosts to encourage industry gatherings which facilitates the development of standards. Standards are important because they drive down the cost for consumers since there are multiple providers of interchangeable devices. Manufacturers benefit because it allows a large number of a product to be created because of having a large market acceptance. In T1A1 they performed perception tests to determine how well people liked different audio and video algorithms that performed compression.

I have also worked with NIST in the ATMForum where they acted as an unbiased expert to verify technical matters. When there are multiple ways of solving a problem, it is very useful to have a knowledgeable entity such as NIST explore the impact and complexity that proposals would have on the outcome of the standard. This service removes the perception that an advocate would have in evaluating the impact of their idea.

A third service that I have observed from NIST is in the IEEE 802.14 committee that is developing Cable Modem standards. I asked David Su to attend because of the need to have independent confirmation of proposals. There are 130 people attending from a number of companies and there have been 17 MAC proposals presented. NIST has the background to help devise tests that may duplicate the type of data traffic in which we eventually may operate the modem. It is important to stress the MAC proposals against this envelope to create a viable product for the consumer.

Since there are a spectrum of user skills in the committee, not all proponents have the expertise to handle the nuances of simulation that NIST can perform. Evaluating a number of protocols using the identical traffic source and measuring the same parameters allows a fair comparison of the proposals. This will then allow the committee to do its job faster and with more certainty because of the assistance of NIST."
(Scientific Atlanta)

"In 1988/89, SWBT in Technology Planning worked with the National Institute of Standards (then known as the National Bureau of Standards). as key players in the establishment of the North American ISDN Users' Forum (NIUF). Richard Stephenson, SWBT, was the first chairman of the ISDN Implementors Workshop which was one of two major arms of the NIUF (the other being the ISDN Users' Workshop). The overall chairman of the NIUF was a high level director at NIST named Shukri Wakid. The NIUF is still an active organization in which NIST plays a major part. SWBT continues to attend NIUF meetings."
(Southwestern Bell)

-Text Retrieval
"The IBM T.J. Watson Research Center develops search technology for applications which deal with large collections of multimedia documents, such as digital libraries and the world-wide web. Much of our work focuses on text, since text search is the most developed of all content searching techniques. Even applications which deal with other content types, such as image and video, typically have a text search component. Also, in recent years, traditional databases have been extended to manage unstructured data such as text, and effective text search is needed in those applications.

As we experiment with new approaches to text search, it is important to measure how effective they are. However, getting objective, quantitative measurements of the effectiveness of information retrieval systems is very difficult, because the measurements hinge on human judgments regarding the relevance of large numbers of documents. It is quite difficult for any single company, still less a university, to muster the resources needed to do this. Therefore, in 1996, IBM plans to participate in the TREC conference organized by NIST, and to use it to assess some text search systems being developed within IBM.

TREC provides two benefits. First, it is a forum in which commercial text search products, commercial prototypes, and research systems can be evaluated using standard protocols. The value of this for a company like IBM is great. Different ways of providing value to users can be quantitatively assessed and objectively compared, which is one of the most valuable ways to evaluate advances in the state of the art. In order to do the comparison properly, all parties must use the same data and methodology. NIST plays a valuable role in providing the benchmarking data and designing standard methodologies. Second, NIST is a neutral party that is independent of any commercial competitor. Thus we are assured that the protocols, data and evaluation procedures used in TREC are not selected in order to favor any product or system.

We believe that participation in TREC will help our company develop products which bring improved functionality and quality to their users by participation in an open, neutral and effective evaluation process."
(IBM Thomas J. Watson Research)

" I am writing to comment on the value of NIST research in text retrieval evaluation to Bellcore and the economy. Information retrieval is one of the success stories of US industry. Trade statistics for 1994 show US exports of information services at $3.2B against imports of $0.4B; even to Japan the US exported $400M of information services and imported only $10M. NIST (under its previous name of NBS) has been involved in research in information retrieval for decades and has helped stimulate and develop this industry.

Most recently, NIST has been sponsoring a series of evaluation tests known as TREK (Text Retrieval Evaluation Confer- encase). These experiments have allowed many companies and universities to compare current text processing methods and improve our algorithms and their implementations. Bellcore has participated in these competitions several times, and we are proud of our performance, which has demonstrated the flexibility, power and generality of our Latent Semantic Indexing (LSI) technology.

The advantages of having this competition for Bellcore include our ability to test and polish our algorithm; to obtain public attention and possible licensees for our patents; and to observe other retrieval projects and see what we can learn from their technology. We have been able to extend applications of our LSI algorithms to areas beyond text retrieval and are currently experimenting with research prototypes in these areas, such as entertainment.

Others have similarly been able to learn from our efforts. For example, the company that markets the Excite search system on the Internet has publicly credited LSI as the origin of their algorithms (see Wired magazine for May 1996). The information retrieval software industry as a whole has gone from under $100M of sales in 1990 to about $650M in 1996 (estimated).

I feel that NIST has performed a very valuable service to the information retrieval business community by running the TREC project and has helped keep the US in the lead in this area of research and stimulated the industry. I hope it will be able to continue doing similar projects."
(Bellcore)

-Speech recognition
It was in 1980 that TI and NIST (then NBS) collaborated to distribute standard speech corpora to evaluate various automatic speech recognizers on a common basis. Thus dawned a new era in which all of DARPA's speech technology development flourished; it did so, mainly because of the timely efforts of Dr. Pallett's group. NIST has played pivotal and often seminal roles in the development and distribution of several key corpora to nurture the technology effort. To wit, here are some key ones: TI-MIT Acoustic Phonetic Data Base (The first, true speaker independent recognition data base of phonetically balanced sentences), Resource Management data base (task specific data where the constraints of the task can be taken advantage of), Air Travel Information System (ATIS) corpora (the first spoken language technology corpora in the world that has given birth all state of the art speech understanding systems including those at CMU, MIT, BBN, SRI and NIST itself), and SWITCHBOARD, a conversational telephonic corpora created by collaboration between NIST and TI and used by several NSA and DARPA contractors. In fact, SWITHCBOARD has been valuable for developing technologies suitable for telecommunication applications such as TI's commercial offerings of Voice Dialing at Bell Atlantic, and Sprint."
(Texas Instruments)

"The Speech recognition research program at IBM has benefited significantly from the activities of NIST in the area of standardized test procedures and coordination of speech data collection and dissemination. IBM has had a long history of research in speech recognition. Our research program in the early '90s was focused mainly on isolated word dictation systems and speaker dependent continuous speech recognition. When research focus within IBM shifted to speaker independent large vocabulary continuous speech recognition, the availability of reference training and test material provided by NIST was an important factor in helping us develop technology for this in a timely fashion.

By providing standardized test procedures and administering system benchmark tests on an annual basis, NIST has contributed significantly to the development of speech recognition technology not only within IBM, but also in the continuous speech recognition community at large. NIST's efforts in this area have helped evaluate the relative merits of different techniques in speech recognition, contributing significantly to the advances in the field. Recently, NIST has played an important role in the collection and dissemination of data from broadcast radio sources. IBM's research program has again benefited from this data, enabling us to improve the performance of speech recognition systems for transcribing radio broadcast news data."
(IBM)

Mrs. MORELLA. Thank you, Mr. Brownstein. It's an honor to have you among my constituency. I always say they're so intelligent, so well-informed. They're leaders in the nation, right, Ms. McCarthy?

[Laughter.]

Mrs. MORELLA. In fact, I must say, the three of you have very succinctly presented testimony. I think we've kind of set a record in terms of time, and again, I repeat to all of you that the totality of your statements, because I notice that you added more material, will be in the record.

I will start off with a couple of questions, turn it over to Ms. McCarthy, and then get back to you again with some more questions.

NIST is merging two existing laboratories to form, as you have mentioned, the Information Technology Laboratory to achieve a stronger focus on the information technology industry. One might wonder how NIST can impact an intensely competitive industry that already spends about $30 billion a year in research and development.

So I just wonder, gentlemen, how do you select research areas to assure that NIST has the greatest impact on the information technology industry and the greatest social return for the Federal investment? It is a tough thing to do, but are there certain criteria standards that are used?

Dr. WAKID. We work very closely with industry on identifying the priorities of their needs and we take a very unique role that industry itself does not provide, that is, the development of tests to establish the merit, the commercial merit of research areas. Our priorities are truly determined by our stakeholders.

Mrs. MORELLA. By the stakeholders?

Dr. WAKID. Our industrial—meaning industry.

Mrs. MORELLA. Do they have a strong role to play?

Dr. WAKID. When competing industrial researchers are trying to evaluate the merits of their work, they tell us to develop tests that are open and pre-competitive that they could use to cross-evaluate the research. So they use us as a neutral technical ground to establish the conmmercial merit of their work.

Mrs. MORELLA. How does NIST assure, if there can be any assurances, that they are not duplicating or preempting activities that would otherwise have occurred in the commercial sector?

Dr. WAKID. What we do is pre-commercial, so the research activities that we broker or the pre-standards or even standardization activity that we technically broker do not have any replicated market existence.

Mrs. MORELLA. Would either of the other two panelists like to comment on that? If not, I will go into another question. Do you think he handled it adequately?

There was discussion about the importance of standards in the information technology, the importance to industry, the Federal Government, and importance also to the consumer. We know that. Yet, Dr. Wakid indicated that the new Information Technology Laboratory will move from the development of standards to the development of conformance testing and test materials. I wondered if you'd like to comment on what the reason is for that shift is in emphasis, or reasons. There is probably more than one reason for that shift.

Dr. BROWNSTEIN. I cannot comment directly, not having been part of the planning process.

Mrs. MORELLA. Right.

Dr. BROWNSTEIN. I think that is a very healthy movement, however. The marketplace speaks rapidly these days about what it will accept as a standard and it turns out that there are any number of organizations that work on standards. I think NIST, by having— or the labs, by having a reasonable representation and continuously scanning what is going on in some of those standards processes has to come by some process to decide where it is going to participate.

Our members pointed out several areas which are, in fact, very forward-thinking for looking at areas that are also very timely and difficult to deal with where they have fallen, that is, NIST has fallen into a happy role as the neutral party that would be trusted in providing performance evaluations so that the industry, for example, that are building cable modems, and make the collective decision about where they want to go. I think that is a good example of NIST moving into an appropriate role in a contemporary issue area.

The broader issue of how to select areas in which to work and which ones to stay in, I think, is well deserving of some systematic planning activity on the part of the labs and I would just defer to Dr. Wakid to tell you about the processes they use because I have not been involved in them.

Mrs. MORELLA. And in so doing, maybe Dr. Roskies would like to comment. Is the decision making process concerning NIST's participation in the voluntary standards process, is it open to all stakeholders, including those in industry?

Dr. ROSKIES. Would you repeat that?

Mrs. MORELLA. I just wondered if in the decision making process concerning NIST participation in the voluntary standards situation, is it open to all stakeholders, including those in industry? I think Dr. Wakid would probably like to comment affirmatively on that, would you?

Dr. WAKID. Mrs. Morella, we do not develop standards. Industry develops standards.

Mrs. MORELLA. Right.

Dr. WAKID. We simply participate and help out. But our key role is the development of conformance tests for standards because the conformance tests capture the technical underpinning of these standards. As soon as a standard starts churning in the marketplace, we just simply use this to say, let's go on to the next priority, homework on our list.

So when we participate in standards committees, they're always open. These are voluntary standards committees. They're open. So the openness of the process is provided inherently by the standard development process and our participation is simply one of getting engaged in an open forum.

Dr. ROSKIES. If I could make a comment on your previous question, I just wanted to say that the formal standards process seems to move too slowly in the information technology arena to be useful.

So moving from developing standards to conformance testing is a recognition of where NIST can play a useful role. Otherwise, you were in the situation where the formal standards bodies were simply catching up to the actual—what the world was doing and there was not much point to it.

Mrs. MORELLA. So it expedites the process, helps to accelerate it, sort of. Will NIST reduce its involvement in helping to set voluntary standards in the information technology industry, or is Dr. Roskies' answer in part indicating that it will be moving ahead faster by that kind of coordination?

Dr. WAKID. We have no intention of reducing our involvement, but we do always select advanced areas to be engaged in. Again, since information technology is a very fast-moving technology, we have to keep up, helping with pushing the envelope so that our industry is competitive. To do so, we have to focus on the advanced area and not on the areas that are close to the marketplace.

Mrs. MORELLA. Ms. McCarthy, we will give you a chance to question as soon as you get back.

Mr. Tanner, we recognize you for any questioning of this first panel.

Mr. TANNER. Thank you. I am sorry I had to step out. I apologize. I have read over your testimony, though.

As you maybe know, earlier this year, the subcommittee held a hearing on the year 2000 problem. I'd be interested in your assessment as to the scope of the problem, what you think the private sector is doing to address the issue, what is NIST doing in this area, and what, if any, recommendation would you have for this Committee or Congress in this matter?

Dr. WAKID. We have published a Federal standard quite some time ago, a few years ago, to explain the problem and to explain how technically to solve the problem. It has been a very old Federal standard. Very recently, we put on the Web a description of how, again technically, this problem can be solved, and everybody has access to our Web to get guidelines.

The actual process of——

Mr. Tanner. May I interrupt? How many hits have you had on that one, do you know?

[The following response was received for the record:]

The Year 2000 home page on the Internet was put on-line on May 2, 1996. As of June 26, 1996, the home page has been accessed 290 times.

Dr. WAKID. My apology. I do not have this number on me. I do want to explain that industry has the same problem, just as government agencies. The problem is generic, all across. The actual process of going through legacy code and making changes to honor the century field is an extremely tedious, expensive problem, again, for industry and for the government. So the actual—again, the actual process of maintaining legacy code that's not documented that the programmers that wrote the code have left companies, what have you, is a very serious, a very significant, very tedious technically a lightweight problem, if you will.

I truly do not know specifically what to recommend to this committee other than the fact that we are sponsoring a big international workshop to educate users on the problem and to allow people who have confronted this problem to share with others case studies of how you go about addressing this problem. This is our next step. We are running an international workshop, again, for promotion of solutions.

Mr. TANNER. I appreciate that. I am afraid that only the people who are aware and who are working on it and are going to do something about it will show up at the workshop, but there's nothing you can do about that.

What would be the wisdom of NIST developing some sort of performance test or some sort of drill to test some of the theories that are floating? Would that be of any use?

Dr. WAKID. I think so. I think we're very willing to establish some kind of test for the integrity of a code that's been modified, if you will. I think that's fine, yes, sir.

Mr. TANNER. Do either of you two gentlemen have anything to add?

Dr. ROSKIES. No. I think it is a good idea to look into this.

Mr. TANNER. That is all I have, Madam Chairwoman. Thank you.

Mrs. MORELLA. I don't know whether Mr. McHale has had a chance to catch his breath. This is the second panel on information technology, if you would like to ask them any questions.

Mr. MCHALE. Madam Chairwoman, I would be disingenuous, not that that's ever stopped me before, were I to thank the witnesses for the testimony that I did not hear. On the assumption that it was wonderfully informative and eloquent, I thank you. In light of the fact that I arrived in the room ten seconds ago, I do not have any questions. Thank you.

Mrs. MORELLA. I guess I will pick up on a few questions, too. The effect of the passage of the Telecommunications Act of 1996 is one I'm curious about. It's going to bring about substantial change in our U.S. telecommunications industry. For example, the Act's provisions will remove previous regulatory restrictions delineating the type of research that some industry laboratories, such as Bellcore and Bell Labs, can undertake, and by some accounts, these two laboratories have performed 80 percent of the R&D in the United States telecommunications industry.

So I wonder, how will the restructuring of the telecommunications industry affect the work that NIST does? Have you had a chance to think about that? Then I wonder if NIST should then ask for a direct industry support for its basic and applied research programs in information technology as the telecommunications industry moves closer to the commercial activities. Dr. Brownstein?

Dr. BROWNSTEIN. The effect that I've seen and the effect that our members have talked about is that industry laboratories are dealing more with development and less with research, more with—have a greater concern for products in the marketplace, getting those products into the marketplace, and far less of a concern with out-year intellectual—development of intellectual resources for future products.

That makes them more interested in seeing organizations like NIST and other parts of the Federal Government supporting basic research and playing the third party sort of neutral host, convener, and assister role that NIST has very well carved out, this laboratory has very well carved out. I would expect that you will see strong interest on the part of industry in supporting those parts of

NIST activities that meet its needs. That will be up to sort of creative management in NIST and creative management in the government to find ways to work with industry.

The Cross-Industry Working Team was created specifically to allow industry to get together and talk about issues that were beyond immediate product cycles, something that it had never really done before. We have all competitors engaging in kind of a strategic assessment of why things work and how some integrity could be maintained in the future.

There is one non-private sector organization in the Cross-Industry Working Team, and that is NIST. When NIST applied, there were major debates about whether we should allow a government agency to participate. In the end, it came down to the same reason that we allow any participant to join—we invite people to join; we are not open to just anyone coming in—and that was because we thought they had a real contribution to make and very much wanted to find a creative way to be able to work with the leadership at NIST in understanding what industry concerns would be several years out.

So I think that's a very healthy sign, that NIST understands this new environment, and I can tell you that industry understands this new environment very well. They've been planning for it for some time and I think you're going to see a large amount of industry support for a continued role of government in a variety of information technology areas that stay out of the immediate marketplace competition.

Mrs. MORELLA. That is an interesting response.

Dr. Roskies?

Dr. ROSKIES. Yes, I would like to add, the panel which I chair conducts an annual assessment of what's going on at NIST in the two laboratories and one of the questions that we ask of NIST management every time is what is the value added of NIST. I don't think it's easy to give a set of simple rules that will allow NIST to pick projects that don't substantially overlap activities that go on in other places, but we have on a case-by-case basis an analysis every year. The management is doing analysis even more than that, but we get a chance every year to review this and one of the questions we ask is whether there is sufficient value added on NIST's part.

So they have to be aware of this problem. It's easy to ask the question. It's not so easy to give guidance on how to choose those projects so that there isn't substantial overlap.

Mrs. MORELLA. So do they respond with what they consider to be the value that was added?

Dr. ROSKIES. Yes.

Mrs. MORELLA. They explain that and what they will do further to enhance it?

Dr. ROSKIES. Yes.

Mrs. MORELLA. Do you want a shot at that, Dr. Wakid?

Dr. WAKID. I'd like really to answer a different spin to your question about telecommunications.

Mrs. MORELLA. Sure.

Dr. WAKID. As you know, with the digital technology, there is a convergence between telecommunications and computing and even display. These technologies are convergent. And so in the future, as they say, a bit is a bit. If you're using it for voice or for a computer transaction or for a video, it's just a bit. The bit streams are all the same. So technology is converging.

The fact that very big think tanks, national think tanks who are very impressive, such as Bellcore, are up for sale, for example, does really mean there is going to be more and more national need for a lab such as NIST to do more work. To me, this is very obvious because the owners of Bellcore have been seven regional telephone companies that don't have a central think tank anymore and I think the nation does need one.

Mrs. MORELLA. Thank you.

Before I ask any other questions, I want to turn it over to Ms. McCarthy for any questioning she may have of this panel.

Ms. MCCARTHY. Thank you, Madam Chairwoman, and with the indulgence of Mr. Tanner, I will proceed, because I'd like to visit with you just a little bit about the development of the encryption standards. I know we're in a debate about the national interests and a need to balance that with law enforcement interests and other aspects of the public interest, but this is going to be pretty critical in the future for U.S. companies and certainly for all civil liberties and open government.

I thought if you'd just reflect on the opportunities that are being provided for our private sector in the process through which these encryption standards are being developed, that would be of interest to me, I know, and I think to other Members on the Subcommittee.

Dr. WAKID. You are asking me the question?

Ms. MCCARTHY. Whichever, all of you or any one of you.

Dr. WAKID. Our role is to help government agencies with the technical protection of unclassified but sensitive information. The question you really asked is way above my civil service grade and I would refer you to the Interagency Working Committee of the National Security Council that really can answer your policy question. We do not deal with policy questions of the nature that you asked.

Ms. MCCARTHY. So they are the ones who decide about private sector involvement in the development of these?

Dr. WAKID. Yes.

Ms. MCCARTHY. You are just one facet of it and have no way in that, nor would you listen to private sector and their concerns.

Dr. WAKID. We are a technical broker, if you will, but purely technical, non-policy. We are a technical broker between the private sector and Federal needs, but we're not a policy broker at all.

Ms. MCCARTHY. I'm reminded that under the Computer Security Act, NIST is charged with broad responsibilities for the protection of sensitive but non-classified information on Federal computer systems. In discharging those responsibilities, NIST has been criticized for focusing on picking technologies for standards such as the product-oriented escrowed encryption standard. Why is NIST not being more policy neutral in that, given what you have just explained to the subcommittee?

Dr. WAKID. What the Security Act gives us is a mandate to publish Federal standards for Federal agencies to protect their unclassified but sensitive information, so this is a purely Federal Act for government agencies who are our stakeholders and we're performing this technical mission.

But the policy question you asked, I thought, has more to do with the balance between industry export needs, and law enforcement needs and national security needs. The balance of these needs and the policy-related issues of these needs are way above my civil service grade is honestly what I'm telling you.

Ms. McCarthy. So NIST will have no say in those decisions?

Dr. Wakid. That is correct.

Ms. McCarthy. What is the role, then, of NIST in coordinating Federal responses to things like unauthorized access to Federal computer systems?

Dr. Wakid. We do help a lot with this. Again, we provide technical protection and technical consulting for building fire walls. We are really very active in this area of protecting government information. This is a technical role that we have been very glad to help out on.

Ms. McCarthy. And in developing that role, what outreach did you do in order to make sure you were choosing the right responses?

Dr. Wakid. We tried to understand how the hackers intrude into various, be it private or government networks, and from the technical know-how, we tried to build protection mechanisms. So we very strongly interact with the private sector in terms of learning what the facts are so we can protect our agencies better.

Ms. McCarthy. Those Federal responses that you've just described development of, are those the kinds of models that the private sector might want to also emulate?

Dr. Wakid. Yes, that's a very good question. Yes, we like to do things that are of common interest to both, again, technical common interest to both, both meaning the public and private sector, yes.

Ms. McCarthy. And in so doing, do you then listen to the private sector in the development of those?

Dr. Wakid. Yes, we do, but the issues related to standards for balance of needs, as you originally asked, again, we're not really the decision makers there.

Ms. McCarthy. So at some level, it's okay to get that private sector input, but not at others?

Dr. Wakid. Yes.

Ms. McCarthy. And who decides where that line is?

Dr. Wakid. The Interagency Working Team. This is, again, a very high-level committee that's part of the National Security Council. It's a very senior committee and the question you asked is truly above NIST, way above NIST.

Ms. McCarthy. I appreciate the role that NIST is playing and I feel very strongly that this is a subject of major interest throughout our nation and certainly the world and something that we need to focus on and we need to be sure that as we develop those standards that we do so with input from all affected as best we can.

Dr. Wakid. Thank you.

Ms. McCarthy. Madam Chair, it looks like Dr. Brownstein wanted to comment.

Dr. BROWNSTEIN. This could easily be the subject of several more hearings. The Cross-Industry Working Team was asked last year by the Interagency Committee of the government to take a look at the process by which information technology security policy is set, not the specific policies but the process, to evaluate its adequacy and to make recommendations. We did that in a report, which has been made public, signed by 45 companies. It was accepted by the committee that asked for it, which has taken many of its recommendations and folded them into a set of recommendations and is proceeding on at the levels above Dr. Wakid's pay grade to try to change some of the way the policy is set.

But it is perceived as an issue, not just on the part of government, because so many agencies have an interest in this, but a problem for industry, because, in fact, there is not a single industry here that speaks with a single voice on the matter. It's a complex matter and I'd invite you to take a look at the report.

Ms. MCCARTHY. I would welcome an opportunity to review the document.

Dr. BROWNSTEIN. I'll leave you a copy.

Ms. MCCARTHY. Madam Chairwoman, thank you for your indulgence on this. I know that Representative Laughlin and others on your subcommittee have interest in this issue, so perhaps there could be a future hearing to review some of these questions that are being posed in our districts.

Mrs. MORELLA. And I know it's the topic of legislation that is before another committee. The encryption concept is critically important, so we'll check on that jurisdiction.

I just want to finally ask you about international standards. Are you satisfied with the present process for international standard setting and the NIST role to assure that our U.S. trade interests are properly addressed?

Dr. WAKID. This is very much the core of what we do. In fact, it's a very key selection criteria for the programs or the standards we decide to take on. If such standards have a potential payoff on large markets, and especially international trade, that will rank them very high on our selection criteria. If we want to take on a technology that has an international trade impact then for apples and apples, that technology will move up on our priority list. The answer is a big yes.

Mrs. MORELLA. Since our other two panelists have probably had some experience in that area, would they like to comment? Do you feel that this answer is adequate? Should there be some changes?

Dr. BROWNSTEIN. I would like to—I don't know how adequate or inadequate it is, frankly, but I'd like to second what I just heard. The U.S. is perhaps the only country that does not have a strategic single representative that goes on and works in its own interest in international standards. We have separate sectors, public sector, private sector. We heard from our members that they like the role that NIST plays, but I think that's—and frankly, having been involved in some of those activities over time, I can assure you we're better off with technical people at NIST playing those roles than we are with diplomatic people attempting to play them. I would just think that that's an area of strong interest in industry and worthy of further consideration.

Mrs. MORELLA. Dr. Roskies agrees.

Dr. ROSKIES. Right.

Mrs. MORELLA. I'm going to turn the chairwomanship into the chairmanship with Mr. Gutknecht as I go over to the Senate to introduce a nominee for our Federal Court system. Mr. McHale has not had a chance to ask any questions. I thank you.

Mr. GUTKNECHT. (Presiding) Thank you.

Mr. McHale?

Mr. MCHALE. Mr. Chairman, thank you.

Gentlemen, I'm not sure if any of you are familiar with the relationship that NIST has had in the past with AT&T, and so perhaps my question is going a little bit far afield, but AT&T, or what had been AT&T, now broken down into independent elements, had a strong historic presence in my district. Lucent, one of the subordinate elements of what had been AT&T, has a very large facility in my district.

Can you give me just a brief sketch of NIST's past relationship with AT&T, and in light of the breakup of AT&T, do you anticipate any change in that relationship with regard to what had been one company now broken down into component parts?

Dr. WAKID. Would you like me to answer this?

Mr. MCHALE. Please.

Dr. WAKID. We've had a very old, ongoing relationship with AT&T. We formed a consortium through a NIST CRADA—you have heard of CRADAs—where AT&T was one of the very key players, as well as some RBOCs, as well as some computer companies and users. This U.S. consortium, that was sponsored by NIST, developed tests for ISDN, Integrated Services Digital Network, under our leadership.

Mr. MCHALE. I'm sorry, would you say that again?

Dr. WAKID. They developed tests, tests mean conformance tests——

Mr. MCHALE. Yes.

Dr. WAKID. (continuing) —that we took as a U.S. contribution to the international standards arena and they turned out to be international standards with our very strong involvement in this. That gave AT&T and our companies a big edge in the international market because international buyers are using international standards that conform to this consortium output.

We have been very involved with AT&T, just like with other companies, on the developing of reliable speech recognition products using the tests that I was talking about, and as a matter of fact, AT&T has used those tests to develop a speech recognition system that they deployed in their network to automate operator services. The claim is made by AT&T that they save $300 million a year because when you talk to an operator now, you are talking to a computer in AT&T. The NIST tests were very key in making the recognition systems more reliable.

We have other numerous examples with Bell Labs and their researchers, and I do not believe that the breakup of AT&T is going to be an impediment to our ongoing relationship.

Mr. MCHALE. When I asked my question, I didn't realize that I was opening the door to such a success story central to the mission historically of NIST, and obviously providing several examples of where that kind of cooperation in the private sector has produced some very positive commercial results.

Have you, since the breakup of AT&T, has NIST proactively taken any steps to guarantee an ongoing positive relationship with the component parts of what had been AT&T, and specifically Lucent? I have a strong interest with regard to that company. If not, let me encourage you to do so.

Dr. WAKID. Yes, I would—I am an ex-employee of Bell Labs, so I think I know the ropes inside AT&T.

Mr. MCHALE. I should also point out, Bell also has a strong presence in my district. I'm evenhandedly parochial.

[Laughter.]

Dr. WAKID. No problem at all.

Mr. MCHALE. Thank you, Mr. Chairman.

Mr. GUTKNECHT. Thank you.

I apologize for being late. I don't have any questions, and I would like to thank the panel for joining us.

Does anyone else have any questions? Mr. Tanner?

Mr. TANNER. No questions.

Mr. GUTKNECHT. I'd like to thank the panel and we'll call up the panel who was listed first who we'll hear from second. Thank you.

Listed first is Dr. Robert Hebner. Welcome back to the Subcommittee. We will allow you to speak first.

STATEMENTS OF DR. ROBERT E. HEBNER, ACTING DEPUTY DIRECTOR, NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY, GAITHERSBURG, MARYLAND; DR. V. THOMAS RHYNE, CHAIR, NATIONAL RESEARCH COUNCIL BOARD ON ASSESSMENT OF NIST PROGRAMS, PANEL FOR ELECTRONICS AND ELECTRICAL ENGINEERING, WASHINGTON, D.C.; AND DR. JAMES A. GLAZE, VICE PRESIDENT, TECHNOLOGY, SEMICONDUCTOR INDUSTRY ASSOCIATION, SAN JOSE, CALIFORNIA

Mr. HEBNER. Thank you, Mr. Chairman, and Members of the Subcommittee. I appreciate the opportunity to discuss the work of the Electronics and Electrical Engineering Laboratory of the National Institute of Standards and Technology.

In my brief opening statement, I would like to highlight five attributes of this laboratory. First of all, the work of the laboratory is, and must be, laboratory-based. The laboratory is global in both its activities and its outlook. The work of the laboratory is highly leveraged. The work of the laboratory is unique, and the laboratory has a very strong industry focus.

First, let me give you an example of what I mean by the work is, and must be, laboratory-based. Several years ago, the Nobel Prize in physics was given to Brian Josephson of England, and subsequently, a second Nobel Prize was given to Von Klitzing in Germany, both for study of the behavior of electrons as you go near absolute zero, how they interact with each other and with outside forces. The staff at NIST took those Nobel Prizing winning discoveries, took them into our laboratory, hardened them, understood them, worked with them. Today, they provide the cornerstones for electrical measurements in the United States and around the world.

The work is global. Any commerce that takes place requires two key elements. One is a monetary system and the second is some way of measuring either quantity or performance. In the area of electronics, the measurement of performance is a continuing and growing challenge and that measurement has to be available for U.S. companies to manufacture products here, to sell them here, and to sell them abroad.

The work is highly leveraged, and I would like to underscore this with an example from an industry which is undergoing significant change right now, the electric utility industry. In this country today, about $200 billion worth of electricity is sold each year. To bill that amount of money, the meter manufacturers, the electric utilities, the States perform about eight million calibrations of watt hour meters. NIST provides the input to that system to assure that it remains accurate by providing fewer than 100 calibrations. We do fewer than 100 calibrations. We support more than eight million industry calibrations, which supports the equitable billing of more than $200 billion worth of electricity in the U.S.

The work that we do is unique. We are recognized as being the nation's measurement laboratory. We are an independent third party. We are unbiased. We're trusted. A good example of that comes from the semiconductor industry. When they had difficulty measuring the quality of the silicon wafers that were being bought several years ago, they came to us and asked us to help them solve that problem. We worked with the industry to develop standard measurement techniques and to look at how the measurements were being made. They wrote their industry standards based on some of the measurement technology we had developed.

In addition, we provided standard reference materials, which we sold to anyone who wanted to buy them so they could verify that their measurements remain consistent. We have in our files a letter from the vice president of a small company which thanked us for providing these because he claimed they had $50 million worth of product they would not have been able to sell had they not had our standard reference material that they could use to show the major suppliers that they actually could do the measurements that they claimed that they could make.

Finally, we have an industry focus. The work is planned in coordination with industry. We work very closely with industry in carrying out the program and, as you will hear, I am sure, from the others on the panel, the work is assessed by industry and we get strong and direct feedback as to how well we are doing.

I welcome your questions.

[The prepared statement of Mr. Hebner follows:]

DEPARTMENT OF COMMERCE

TECHNOLOGY ADMINISTRATION

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ENGINEERING LABORATORY

BEFORE THE

HOUSE SCIENCE SUBCOMMITTEE ON TECHNOLOGY

June 25, 1996

Madam Chairwoman and Members of the Subcommittee, I appreciate the opportunity to discuss the work of the Electronics and Electrical Engineering Laboratory of the National Institute of Standards and Technology. The Electronics and Electrical Engineering Laboratory (EEEL), through its technical laboratory research programs, supports the U.S. electronics industry, its suppliers and its customers, including the Federal government, by providing the measurement technology that U.S. industry needs to improve its competitive position and the government needs to improve efficiency in technical operations.

This measurement technology is required for industrial research and development, for improvements in the design and manufacturing of quality products, for proof of performance, for marketplace transactions including the entry of U.S. products into international markets, and for product application. The measurement technologies resulting from this program support the fundamental electronic technologies of semiconductors, magnetics, and superconductors that underlie all modern electronic systems; electronic components technologies for information and communication aplications, including fiber optics, optoelectronics, microwaves, and video; electrical power systems; the advanced manufacturing of electronic products; and electronic instrumentation.

EEEL provides the national reference standards that are the fundamental basis for all electrical measurements in the U.S. and are required to assure the accuracy of industry's measurements. To provide consistency and accuracy, **all measurements must ultimately be referred back to national reference standards.** For example, to measure silicon resistivity, a semiconductor manufacturer needs calibrated instruments and standardized procedures to be assured of accurate results. In our efficient industrial system, the semiconductor manufacturer relies on equipment manufacturers and private sector calibration laboratories to provide calibrated instruments. To certify the accuracy of the instruments being manufactured, the instrument manufacturer must have available appropriate standards calibrated in terms of national electrical standards. The instrument manufacturer either maintains these and has them compared regularly with NIST standards, or uses a private sector calibration laboratory which provides the reference to the national standards maintained by NIST. This process is called traceability.

EEEL is the linchpin of this process for electrical measurements. It maintains all the national reference standards for electricity for the U.S. and provides appropriate calibration services and calibrated artifacts to private industry and other government agencies. Realizing national reference standards in terms of their internationally agreed-upon definitions is technically difficult and requires a dedicated laboratory capability. NIST has that legally-mandated responsibility for the United States.

The NIST Laboratories must do more than simply maintain standards if the U.S. is to have the necessary measurement systems. The second (and larger) part of the problem is the necessity of having available suitable, appropriate, and meaningful measurement methods that permit users to correctly use available instrumentation and standards to perform their needed measurements at the required accuracy. EEEL metrology research is focused on both components.

The primary clientele EEEL serves is the electronics industry, taken very broadly. The measurement capability provided by EEEL programs supports entities ranging from giant electric utilities and large aerospace companies to specialized instrument manufacturers employing just a few individuals EEEL's electrical measurements help advance the $350 billion per year U.S electronics sector. For example, EEEL provides microwave antenna measurements used by every major U.S. aerospace company, thus supporting a U.S. microwave industry which supplies about one half of the $60 billion world microwave equipment market EEEL provides national reference standards that are needed to assure the accuracy of the electric power meters in every home and business in the U.S., thus supporting the metering of nearly $200 billion per year of electricity. EEEL provides measurement capability reflected in voluntary industry standards affecting the manufacture of every new U.S.-made optical fiber communications line, thus supporting a U.S. fiber optics industry supplying a domestic market approaching $3 billion and competing in a world market in excess of $5 billion.

EEEL's estimated FY97 staffing level is 283 full-time-equivalent staff, funded through direct congressional appropriations, transferred funds from other government agencies and industry, and fees received for calibration services. EEEL provides the largest share, over 40 percent, of all NIST's calibration services, representing $2 million in calibration fee income.

Why NIST/EEEL?

NIST's role is to remove measurement barriers that require NIST's special characteristics an impartial position, recognized measurement capability, expertise in a wide range of measurement areas, direct access to national standards, and imprimatur as the lead U.S agency for measurements. These characteristics permit NIST to do what individual companies cannot do: gain access to industry information needed to resolve industry-wide measurement problems, develop measurement solutions and national reference standards that benefit the industry as a whole across diverse product lines, and gain acceptance of those solutions by U.S industry and its international customers so that U.S. products can be sold efficiently here and abroad.

Typical examples where EEEL performs this unique role are the following:

- EEEL is working with the Semiconductor Industy Association (SIA) on the National Technology Roadmap for Semiconductors to identify and respond to key measurement technology needs that must be met in the next 15 years for the industry to manufacture future generations of electronic chips. The SIA has written a strong statement of the need for metrology, and further, of NIST's role: **"NIST is the only place in the U.S. where the broad range of measurements needed for semiconductor processing are routinely and systematically developed."**[1]

- EEEL develops and maintains the national standards for laser power and energy. A major instrument manufacturer has reported that the standards from EEEL provide the infrastructure for its business because the accurate measurement of optical power is common to nearly every type of fiber optic test instrument being manufactured. NIST **is the only organization recognized as capable of developing unbiased standards** as it has the technical expertise required for developing such standards and has no financial stake in the industry.
- New information technologies increasingly incorporate wireless communication systems and displays. EEEL is developing and maintaining the national impedance and microwave power measurement standards which underpin the measurements needed for wireless communication. Similarly, EEEL is developing test procedures needed to permit international commerce in displays. These procedures provide unbiased comparative measures for U.S. manufacturers who purchase displays for incorporation into their systems. In both these cases **the international reputation of** NIST **for impartiality and accuracy** is required to attain the recognition needed to support international trade.

Determining Industry and Government Needs

The specific client needs addressed by EEEL are driven by the fast moving world of electronics—**an industry that continues to outstrip its capability to measure and control its materials and processes and evaluate its products**. There is also a broad new recognition in industry of the significance of accurate physical standards and of the processing and performance standards that depend on them. This comes about as industry is forced to meet conformity requirements in the international arena and cost and quality requirements in its manufacturing plants. All of these pressures demand advances in measurements.

EEEL depends on continued close interaction with the industry to help determine client needs and plan our response. For example, just in the past two years we have sponsored or co-sponsored nine major workshops (see Appendix A) and participated in several national technical roadmapping activities—which are particularly useful in identifying industry needs. EEEL staff also actively participate in conferences, make visits to industry laboratories, hold telephone consultations, conduct and attend numerous meetings. Altogether, we've collaborated with, or served in some substantial way, over 2000 different organizations in the past two years. We typically receive useful programmatic guidance and feedback from these collaborations.

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[1] *Semiconductor Technology—Workshop Conclusions*, Semiconductor Industry Association (November 17-19, 1992).

EEEL Program Selection

In the face of the large range of needs and our limited resources, we must choose and plan our projects very carefully to maximize their impact. We have long-established, written criteria to help in our project selection; these are summarized in Appendix B. Additional information about our program planning process is published yearly in our program plan which includes a summary of all the current-year activity in the Laboratory, and for each technical area, specific accomplishments, a description of the significance to industry and government, quantitative milestones for the next year, and an updated five-year plan giving a longer term view.

EEEL also conducts selected area-specific, detailed studies which provide part of the basis for our plans and budget initiatives. Nineteen examples of significant studies (some unpublished) are included in Appendix C. A current example is in our program on electromagnetic compatibility (EMC) which is a critical issue in the industry. First we conducted an impact study showing a high return on our present work, but nevertheless we reviewed the current program to see if our impact could be improved. Next we analyzed commercial and government EMC standards to disclose measurement need, and then we conducted a field study involving 37 organizations and 90 people to carefully define specific measurement requirements. And finally, to refine the priorities of a very broad range of requests for assistance, we held a follow-on workshop and have now reoriented our program to concentrate on the two highest priority topics.

EEEL also develops substantial technical-area reviews that summarize major industrial measurement requirements. In recent years, they have been published in a document "Emerging Technologies in Electronics... and their Measurement Needs"[2] and more recently "Measurements for Competitiveness in Electronics."[3] These have both received industrial review at levels from management to the bench to assure their relevance and validity. Although they were developed for our internal planning, we have already received over 900 requests for copies of "Measurements for Competitiveness in Electronics." Our clients have told us they find it useful for their *own* internal planning.

Evidence of Impact of EEEL Programs

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[2] *Emerging Technologies in Electronics... and their Measurement Needs*, NISTIR 90-4260 (February 1990).

[3] *Measurements for Competitiveness in Electronics*, NISTIR 4583 (April 1993).

There is considerable evidence that our priority-setting process and laboratory efforts work well. Over a dozen formal econometric studies conducted by external experts have shown our work has paid off. For example, **our work in electromagnetic interference saved automotive manufacturers alone more than $16 million a year** and, overall, resulted in a social rate of return on investment of 266 percent.[4] Our optical fiber work yielded 423 percent.[5] In studies in four semiconductor areas the return varied from 63 to 181 percent.[6] As our program resources are small compared to the overall needs we can efficiently target high impact areas, thus our median value of social rate of return on investment is well over twice the 56 to 99 percent return found for typical private sector innovation.[7] (The economic experts that helped us in these studies assure us that ours are conservative figures since they are typically based on just a single step in the economic commercialization process and do not include many downstream benefits which themselves are very significant.)

We constantly inquire of our clients about their use of our work and collect evidence of our impact. The Director of the Instruments Division of the Auburn Group of Coherent (a U.S. laser manufacturer) says the **NIST approach** for laser profiling measurements **"will provide the laser industry with standards in an important area that has continued to evade us for almost 30 years."** The President of Rotek Instrument Corporation (a small U.S. electrical instrument manufacturer) has told us, "The technical assistance you provide throughout the year greatly assists us in maintaining our standards and enables us to provide the best service possible to our customers." The Chief Engineer of the Motorola Electromagnetics Laboratory said, "...the technical contributions of NIST to the industry have been outstanding throughout the years." The President of Optical E.T.C., Inc. had this to say: "As a small business, OETC could not have reasonably developed the TFPD [thermal flat panel display] technology without the collaboration of NIST personnel and access to the extensive facilities at NIST...."

The bottom line is that through its focus on measurement research and services, EEEL really makes a difference to the electronics industry. **Our metrology activities are unique, are badly**

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[4] Albert N. Link, *Estimates of Economic Impact of NIST Research in Electromagnetic Compatibility/Interference (EMC/EMI) Metrology*, p. 12-18 and 20 (December 1991).

[5] Albert N. Link, *Economic Impact of NIST-Supported Standards for the U.S. Optical Fiber Industry: 1981 - Present*, p. i-ii, 16-17, and 35-39 (February 1992).

[6] Charles River Associates Incorporated, *Productivity Impacts of NBS R&D: A Case Study of the Semiconductor Technology Program Summary Volume*, pp. 3, 19 and 20 (June 1981). Albert N. Link, *Economic Impact on the U.S. Semiconductor Industry of NIST Research in Electromigration*, pp. ii, 1 and 30-39 (January 1992).

[7] Edwin Mansfield, John Rapoport, Anthony Romeo, Samuel Wagner, and George Beardsley, "Social and Private Rates of Return from Industrial Innovations", *Quarterly Journal of Economics*, Vol. 91, p. 233 (May 1977). J.G. Tewksbury, M.S. Crandall, and W. E. Crane, "Measuring the Societal Benefits of Innovation", *Science*, Vol. 209, p. 659, (August 8, 1993).

needed by our sophisticated industry, and have a major impact in improving productivity and profitability.

A few examples serve to illustrate the breadth and impact of our technical expertise.

- Watt-hour meters are used to meter nearly $200 billion worth of electricity annually in the U.S. The meter manufacturers, the electric utilities, and State regulators perform about 8,000,000 calibrations of these meters per year. EEEL performs about 100 calibrations per year, which are sufficient to maintain the consistency of the system across the Nation. Our research in support of electric utilities power and energy calibrations shows that our **laboratory research has a social rate of return of more than 400 percent**.[8]

- International trade, particularly in high technology products, depends on accurate measurements In the electrical area, for example, EEEL is continually involved in numerous international comparisons, conducted between national measurement laboratories under the auspices of the International Bureau of Weights and Measures, to ensure the equality of electrical units worldwide. **These comparisons are a factor in preventing the creation of non-tariff trade barriers** requiring U.S. instrumentation and components to be re-certified in the country of import, resulting in extra delay and cost. In extraordinary cases, however, EEEL has been asked to help resolve specific problems, including the export of transformers to an African country, the export of electronic instrumentation to Europe, and the export of watt-hour meters to China. The companies in the other countries suspected the accuracy of tests conducted by private U.S. companies until it was demonstrated that the measurements were consistent with the official measurement systems developed and maintained by EEEL.

- EEEL introduced the theory and methods that permit indoor, near-field scanned measurements of antennas to replace costly and low-resolution outdoor measurements, and further, to allow diagnostics and adjustments to be made in phased array antennas during actual manufacture. As a result **some 15 U.S. companies have installed 40 near-field calibration facilities**. One company has reported a $35 million saving and another a reduction in testing time from a month to 12 hours using such facilities.

- The EEEL microwave program has introduced new measurement methods based on transmission line test structures formed directly on the semiconductor wafers. This work disclosed large errors (greater than 30% in some cases) in traditional industrial measurements that previously frustrated design and reduced productivity. These results have been incorporated in commercial test instruments and adopted by major U.S. companies. Eminent people in the field have praised this work, one calling it "**the greatest advance in microwave circuit theory in 50 years".**

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[8] Albert N. Link, *An Evaluation of the Economic Impacts Associated with the NIST Power and Energy Calibration Services*, Electronics and Electrical Engineering Laboratory, National Institute of Standards and Technology, Report No. NISTIR 5565 (January 1995).

- Our most basic measurement research has to advance rapidly to keep abreast or ahead of this very fast moving industry's practical needs. For example, as one result of EEEL research in superconductivity, we discovered how to make operable a large array of Josephson junctions. Those arrays now serve as the national standard for the volt, not only in this country but in many others as well. And our development of a still larger array, with over 20,000 junctions providing a ten-volt output, turned out to be essential for Hewlett-Packard to be able to introduce the world's then most advanced and accurate multimeter. H-P and other manufacturers use the array for manufacturing and quality control, and small companies have commercialized the NIST instrumentation that operates the arrays. So, now **the best physical standard for voltage in the world is at work every day in manufacturing plants** and EEEL faces a new challenge in meeting the needs of the future.

- As part of its work to improve measurements for power transistors, EEEL has developed an electro-thermal model for the insulated-gate bipolar transistor. This has led to a revolutionary concept that permits system manufacturers to simulate computationally the device performance in their system, and to make a purchase decision, *before the device is fabricated* This research led to an effort by Motorola and Analogy, Inc. that according to Electronic Engineering Times, "has customers getting 'virtual prototypes'...in lieu of actual samples.... **Using simulation models will typically shave five months off the development cycle**, which for power systems often runs about a year.... This is a new paradigm in power electronics." The model has also been adopted by the Ford Motor Company in the design of electronic systems for its products.

- Over the years, EEEL work with the optical fiber industry has provided the technical basis for over two dozen Telecommunications Industry Association (TIA) standards, leading the President of the TIA to say, **"Without the NIST assistance and leadership, the U.S. fiber optics industry would not be in the competitive position it is today."** More recently it was found that U.S. manufacturers were not competitive with overseas manufacturers who could make optical fibers with the circular cross-section with sub-micrometer tolerances needed to avoid large signal losses in multiple connections. Responding to a TIA request, EEEL provided U.S. manufacturers with improved measurement methods and a standard reference material (SRM) that solved their problem, and now all the fiber-drawing towers of the major U.S. manufacturers use these SRMs for production control.

- Software-based electronic instruments, typically using analog-to-digital converters, require thousands of measurements for evaluation and demand a new test strategy for cost effective use in manufacturing and evaluation. EEEL developed an analysis method that permits a greatly reduced data sample to give accuracy effectively equivalent to a full test. For example, the 8192 measurements for a 13-bit converter can be replaced by only 64 measurements, **reducing test time 90 percent**, to 2 seconds. One manufacturer expects that using this improved method will reduce their test cost from $8 to $3 per $25 converter, translating to an annual saving of $400,000.

- In recent work in magnetics, EEEL developed measurement methods to study nanoscale friction forces on recording disks in a collaboration with a major manufacturer of computer disk drives. The forces arise from sticky projections 20 or 30 nanometers high on a hard disk platter which interfere with the reduced flying-height of the magnetic-signal reading heads needed for increased storage density. EEEL showed how atomic force microscopy could be adapted to measure the lateral forces involved thus **providing the industry with a tool** with which to identify the sources of increased friction.

The National Semiconductor Metrology Program

A topic of emphasis in this hearing is NIST's National Semiconductor Metrology Program which is a NIST-wide program managed by EEEL. The semiconductor industry's measurement needs are constantly escalating, being driven by the increasing complexity of integrated circuits and the requirements for tighter control of more numerous and more sophisticated manufacturing processes. Here the industry is defined broadly to include integrated circuit manufacturers, materials suppliers, and makers of semiconductor manufacturing equipment. Three important reasons lead NIST to work intensively to meet the measurement needs of the semiconductor industry

- First, **that industry is critical to the success of the electronics industry**. And electronics in turn is a critical element in the modernization and success of very nearly every segment of our economy including automobiles, banking, manufacturing, communication, defense, entertainment, computers, and transportation.

- Second, **making semiconductors is an extraordinarily measurement intensive undertaking**. A wide range of specialized scientific and engineering skills is required to develop and improve the measurement understanding and application techniques that are needed. The Semiconductor Industry Association made this statement about the importance of metrology to its industrial processes: "Metrology is a key enabler for equipment design and manufacture, for materials production, for generating data for modeling throughout semiconductor manufacturing, and for final test and evaluation. Without satisfactory metrology, the industry ... will cease to be competitive."

- Third, the Semiconductor Industry Association's National Technology **Roadmap for Semiconductors provided clear input from industry** on what technologies would be needed and when.

Early EEEL Contributions

EEEL has a 40 year history in supplying measurement technology to the semiconducor industry. These contributions began with two small projects that have benefitted the industry by more than $30 million (more than 100 times the cost of the work) in marketplace exchanges alone. These projects, and those that have followed, have been selected by working with the semiconductor manufacturers and equipment suppliers to understand their needs for measurements and to match the most important of those needs with EEEL's available resources. **The products of this interactive process are relevant to real needs, workable, and well documented**, as typically demonstrated by interlaboratory test. Many are delivered via physical Standard Reference Materials for direct calibration of measurements in the client's plant. Often significant training is available to assure proper application of the measurement technique. And, as indicated earlier, EEEL has studied the economic impacts of its semiconductor work to understand its value in those terms.

Some example EEEL contributions are:

- Industry recognized that unpredictable wire bond failures were a major system reliability problem but did not know why the failures were occurring. As EEEL staff developed the measurement methods destined to solve the problem, they discovered many factors underlying the failures. This work established a new metallurgical understanding and new procedures that **led to radical changes in the design of commercially available equipment**. It also increased productivity in high reliability circuit manufacture by as much as 35 times.

- EEEL work on photomask linewidths led to the reduction of intercompany measurement discrepancies by an order of magnitude, stimulated the production of new commercial instrumentation, extended the range of use of optical microscopes, and produced a net saving of $177 per $1000 mask for a $30 million saving to mask manufacturers alone, according to a 1982 study. The provided **techniques and calibration standards have been adopted industry wide**. Hewlett-Packard, IBM, and Texas Instruments, for example, ceased use of their different internal standards and adopted those of NIST.

- Developing reliable mathematical models is an essential part of EEEL metrology research. Electromigration failures occur at high current densities when the electron flow in the semiconductor device actually moves material and breaks a connection. Our electromigration results have been used by at least 14 companies, and an external study has estimated industrial savings of $26 million in return for the $1.6 million spent on the project. Further, the results are the basis for three industrial standards, and one U.S. company, Sienna Technologies, Inc., supplies test stations and a library of standard structures based on EEEL's recommendations.

The NSMP

The National Semiconductor Metrology Program draws on the breadth of expertise in the NIST Laboratories as well as having collaborative relations with a wide range of organizations including Sandia National Laboratories, Lincoln Laboratories, Semiconductor Research Corporation, and SEMATECH, in addition to those already existing with the industry.

Internally, program selection has been aided substantially by the development of the National Technology Roadmap for Semiconductors, which identifies in detail the technical needs of the industry projected over the next 15 years. The Roadmap and its predecessors have repeatedly identified metrology, the science of measurement, as one of a very few "crosscutting" issues, i.e., issues that affect every area of semiconductor design, development, and manufacturing. With initial funding of $4.8 million, a current funding of about $10 million and an annual funding objective of $25 million, the work is focused on the mainstream technology addressed by the Roadmap, digital silicon integrated circuits.

The NSMP supports measurement development programs in silicon semiconductor materials; dimensional measurements for patterns on the surface of silicon wafers; trace moisture in process gases; physical and chemical properties data for modeling chemical reactions; pressure, composition, and flow rate of process gases; boron implants in silicon; surface microroughness of silicon wafers; improved high-temperature thermocouples; properties of polymers for device packages; and intensity of ultraviolet light for making fine patterns on wafer surfaces.

Among the results to date have been Standard Reference Materials for oxygen and boron in silicon, new in-house designed and constructed equipment for absolute moisture measurements in gases to extremely low levels, electrical measurements of alignment between successive layers of materials with accuracy of less than 30 atom spaces, calibration services for ultraviolet lightmeters, greatly improved understanding of the chemistry of electrically driven film deposition processes, and better knowledge concerning the scattering of light from highly polished surfaces that affects the detection of small particles of contaminating materials on those surfaces. These contributions are too new to permit full evaluation of their technical or economic impact, but as an example, the last of these has already solved a major problem for a leading U.S. manufacturer of semiconductor manufacturing equipment.

Funding increases for NSMP requested through the Budget Initiative process for FY97 will be used to address metrology issues associated with 193 nanometer optical lithography. Recent changes in the missions (and funding policies) of both DARPA and SEMATECH coupled with fundamental business changes for larger firms like IBM Microelectronics and AT&T/Lucent Technologies have left a void in this critical path development which NIST is working to fill, primarily through active partnerships with other organizations. The **end goal is to enable at least one domestic supplier to produce a viable advanced optical lithography tool** to meet the 180 to 130 nanometer technology needs on the schedule of the National Technolgoy Roadmap for Semiconductors so that U.S. industry will not be constrained to buying next generation semiconductor manufacturing tools from foreign sources.

I would like to conclude with five fundamental points about our research programs. These programs are laboratory based, and need to be, support the globalization of trade, are a high-leverage activity, are unique in the United States, and are coordinated with industry. Thank you for your attention and I will be pleased to answer any questions you may have.

Appendix A

EEEL Workshops
(March 1994 - April 1996)

1. International Workshop on Semiconductor Characterization: Present Status and Future Needs

2. Testing for Wireless Applications

3. Compound Semiconductor Technology
(NIST/SEMI)

4. Measurement and Characterization of Ultra-Shallow Doping Profiles in Semiconductors
(NIST/American Vacuum Society/Intel/Microelectronics Center of North Carolina/SEMATECH)

5. EMI/EMC Metrology Challenges for Industry: A Workshop on Measurements Standards Calibration and Accreditation

6. Display Materials Consortium Workshop

7. Antenna Parameter Measurement by Near-Field Techniques

8. Testing Strategies for Analog and Mixed-Signal Products

9. Advanced Digital Video in the National Information Infrastructure

Appendix B

Summary of EEEL Program Selection Criteria

1. FIT TO MISSION

Goals Served - Primary goal is to strengthen the U.S. economy via contributions to improving the competitiveness of U.S. industry.

Customers Served - Industry primarily, then Government, then educational institutions.

Deliverables - Measurement accuracy and capability are highest priority deliverables.

Steps Served - Service to marketplace exchange is primary, service to manufacturing a close second.

Uniqueness - Only NIST can and will.

2. IMPACT IF SUCCESSFUL

Market Size - Work supporting a large market (direct and indirect) higher priority than a small market.

Market Immediacy - Work supporting a market that currently exists gets a higher priority than work supporting a market that won't exist until some time in the future.

Timeliness - Relative to the time of need, work that will be delivered when *first* needed gets a higher priority.

Criticality - The "stopping power" of the lack of the NIST contribution. A product cannot be made, or marketed, or supported without the NIST work.

Sensitivity - Willingness of industry client to provide support for the work.

Visibility - The more visible the impact of the proposed work, the higher the priority

Commitment - How efficiently staff time is used; one-time , periodic, or continuous.

3. PROBABILITY OF SUCCESS

In completing technical work and achieving adoption by client; based on adequacy of staff, equipment, and funding.

4. INSTITUTIONAL HEALTH

Projects that strengthen the organization and staff, promote growth and recognition.

Appendix C

Examples of Special EEEL Planning Studies

Silicon resistivity
Wirebonding
Photomask linewidth
Magnetics calibration
Magnetics program
Center (Laboratory)-wide calibration services policy
Dielectric materials
Low-frequency electronics
Lightwave metrology
Microwave metrology
National laboratories calibration service benchmarking
Advanced semiconductor metrology
Lasers
Optical fiber metrology
Optical fiber sensors
Electromagnetic compatibility
Video
Strategic planning studies
Fields and interference metrology

Robert E. Hebner
Acting Deputy Director
National Institute of Standards & Technology

Robert E. Hebner received his Ph.D. in physics from the University of Missouri in 1971. He joined what was then the National Bureau of Standards as a presidential intern. Since that time he has advanced through increasingly responsible positions and is currently Acting Deputy Director of NIST.

His activities with other agencies have included assignments at the Office of Management and Budget, at Sandia National Laboratories, and most recently, at the Advanced Research Projects Agency of the Department of Defense. He has served as a member of the Advisory Committees for two NATO Advanced Study Institutes and has participated in the organization of many national and international conferences. Dr. Hebner was a member of the review committee for U.S. Department of Energy's Office of Energy Storage and Conservation in 1986 and on an NSF Panel for Engineering Research Equipment Grants. In addition, he served on the National Research Council's Committee to Conduct an Assessment on Establishing Underwater Arcs and Flames. He is a member of a Federal interagency committee to coordinate the U.S. research and communication program on the potential health effects of electric and magnetic fields. He was the principal investigator and the government's key witness in a celebrated court case involving an alleged novel approach to the efficient generation of electricity.

Throughout his career, Dr. Hebner has been active in technical activities having authored or coauthored more than fifty technical papers and reports. He is the past president of the Dielectrics and Electrical Insulation Society of the Institute of Electrical and Electronics Engineers. In addition, he has served on numerous technical committees which develop voluntary standards for the electric utility industry.

Dr. Hebner is a member of the American Association for the Advancement of Science, the American Physical Society, and is a fellow of the Institute of Electrical and Electronics Engineers.

The awards that he has received include the U.S. Department of Commerce Silver and Bronze Medals and the 1990 Harry Diamond Memorial Award given annually by the Institute of Electrical and Electronic Engineers for outstanding technical contributions in the field of government service. The award cites Dr. Hebner's contribution to the development of electrical measurements and standards for the electrical utility industry.

Mr. GUTKNECHT. Thank you, Dr. Hebner.

I think before we take any questions we will go to Dr. Rhyne and Dr. Glaze and then we will have questions. Dr. Rhyne?

STATEMENT OF DR. V. THOMAS RHYNE

Dr. RHYNE. Thank you very much. It's my fault, or actually, it's the fault of a major domestic air carrier who had a little computer trouble this morning that I forced the switch and I appreciate your being flexible and I apologize.

I want to also thank the Members of the Committee for inviting me and for having this opportunity to comment on the National Institute of Standards and Technology's Electronics and Electrical Engineering Laboratory, and my focus is going to be on the assessment process which provides an annual measure of the effectiveness of this key government program.

As my name tag shows, I'm Tom Rhyne. I'm the current Chair of the National Research Council's Panel on Assessment for what we commonly call EEEL. When you look at Electronics and Electrical Engineering Laboratory, I think you can understand why we simplify to that.

I've been involved in the assessment process at NIST for over five years and I've worked in national and international standards bodies for over 20 years. I currently work within the semiconductor product sector at Motorola. Prior to that, I worked at the Microelectronics and Computer Technology Corporation, which you probably better know as MCC. I've also spent about 20 years teaching electrical engineering and computer engineering at a number of U.S. universities.

Each year, the work of the panel consists primarily of performing an assessment of the technical work being conducted by the EEEL, the general nature of which and some of the highlights of which have already been described to you by Dr. Hebner. The current panel consists of some 20 senior engineers and scientists selected from 14 U.S. corporations, including my own company, Motorola, AT&T, Bell Laboratories, Scientific-Atlanta, Corning, Hughes Aircraft, American Superconductor Corporation, and Texas Instruments, just to name a few. We have members from two national consortia research centers, the Semiconductor Research Corporation in North Carolina and SEMATECH, and one university.

In performing the annual assessment, each of these men and women spends as much as a week away from their normal technical and managerial duties traveling to Washington or Colorado to discuss the laboratory's technical activities with the managers and technical staff at the laboratories, and therefore, the committee, the panel works together to prepare an extensive written report on their findings.

All of this work is performed by these men and women on a purely pro bono basis, a significant tribute to the importance that the employers of these people and the companies those employers represent place on this particular government laboratory. In fact, in and of itself, the willingness of the corporations to allow us, as panel members, to spend this time away from our jobs is a major measure of the high regard which the associated United States industries place on the work of the EEEL.

My written remarks, which I believe have already been provided to you in advance, serve to summarize the most recent findings in 1995 of the Panel on Assessment. They touch briefly on the work being performed in the areas within which the EEEL focuses, including areas such as electricity, which includes both basic electrical standards and support for the U.S. electric utility industry, semiconductor electronics, electromagnetic fields, electromagnetic technology, which is an area that includes superconductivity, a very important field in the current time, and optoelectronics, and also the National Semiconductor Metrology Program. All of these fields are obviously of major importance to our national interests. Additional detail is available in the published assessment, and if you don't have a copy, I am sure that the National Research Council will be glad to provide you one.

In my brief oral remarks, I can't really cover all the details, but I can make one summarizing statement; NIST's EEEL is doing an excellent job in meeting as much of the metrology and standardizations needs of the industries it serves as its current resources will allow.

The major problem that's been identified by the panel over the last several years is the mismatch between available resources and known needs, especially in the last few years as what NIST calls OA, or other agency funding, has shifted from defense agencies and become diminished. That shift away from military funding has been managed very well by this part of the NIST operations, but as commercial needs have expanded and as the costs of making increasingly more accurate measurements in the electrotechnical domain have grown, the challenge before the EEEL has increased and they now face and will continue to face a very difficult form of what I call technological triage, where they, as the managers of the laboratory, must select which projects to start, which projects to maintain, and which projects to stop.

They do this by working closely with those industries that they serve in a highly symbiotic relationship, as will be well illustrated by the laboratory's work in conjunction with the National Technology Roadmap for Semiconductors, which Dr. Glaze will describe to you. In that role, the EEEL is providing much needed support to a very important sector of the U.S. industry, and without such support, the global industrial stature of the U.S. semiconductor industry would certainly be significantly eroded.

There is one point I want you to understand. Standardization and metrology have become key weapons in the international marketplace, and with the countries of the European Economic Community and the Pacific Rim often voting as blocks to enforce their preferred national standards on the international community, the work of the EEEL in proposing new electrotechnical standards, new metrology methods, and in helping U.S. industries to deploy rapidly newly adopted international standards is a critical enabler to the U.S. global industrial competitiveness.

Speaking for the entire panel, we commend to you the work of the EEEL in meeting that challenge. Clearly, this is one area of government activity which provides excellent return on investment. Thank you.

[The prepared statement of Dr. Rhyne follows:]

Testimony by Dr. V. Thomas Rhyne, Chair
National Research Council
Panel for Electronics and Electrical Engineering
to the hearing on

"Oversight Review of Research Laboratory Programs at the National Institute of Standards and Technology"

Held by the
Subcommittee on Technology, Committee on Science
U.S. House of Representatives
~~April 30, 1996~~
JUN 25 1996

Ms. Chairwoman and Members of the Subcommittee:

I am pleased and privileged to address you today as the Chair of the National Research Council's Panel for Electronics and Electrical Engineering, one of seven panels of the Board on Assessment of National Institute of Standards and Technology (NIST) Programs. My own training is in electrical engineering, and I am currently the Manager of Strategic Programs within the Semiconductor Products Sector of Motorola, Inc. I have been employed in the electronics industry for over thirty-five years, including sixteen years as a Professor of Electrical Engineering at Texas A&M University. I have served for five years on the Board of Directors of the IEEE, and have been Chair of the Panel for Electronics and Electrical Engineering since 1993 The Panel currently has twenty members representing a variety of areas of expertise in electronics and electrical engineering.

The work of the Panel consists primarily of performing annual assessments of NIST's Electronics and Electrical Engineering Laboratory, more simply referred to as the EEEL, the general nature of which has been described to you by its director, Dr. Judson French. This work is purely *pro bono*, with the Panel members taking time away from their normal jobs to spend as much as a week each year visiting the Laboratory, discussing its technical activities with the Laboratory managers and technical staff, and preparing an extensive written report on their findings. The current panel includes employees of sixteen different U.S. electronics companies, a tribute to the importance those companies assign to the task of assessing the activities of this key government laboratory.

My remarks today summarize the findings of the Panel during its 1995 assessment.

In 1995, as has been the case over the past several years, the Panel found the programs of the EEEL to be well managed and of high quality. The selection of projects within the Laboratory generally appears to be well matched to the current needs of its broad range of industrial customers, including the semiconductor industry, the electric power utility and equipment industries, developers and manufacturers of microwave devices and other wireless technologies, and the magnetic data storage industry. This is a very broad charter, however, and given the rapid pace of developments in the technical and scientific areas associated with these industries, coupled with the limited resources available for supporting its work, continual refinement of the Laboratory's priorities is a major challenge to its managers. As a result, the Laboratory has created a formal prioritization process which has proven to be largely effective in meeting this broad challenge.

During its assessment activities, the Panel has identified numerous examples of work within EEEL which has resulted in measurable impact on key sectors of U.S. industry. For example, a NIST-developed digital impedance bridge has allowed the first significant improvement in inductance measurements in 40 years. Based on this advance and other related NIST improvements, uncertainties in calibration services for capacitance, inductance, and loss will soon be decreased by a factor of 10 or more. The Laboratory has also refined electrical methods for measuring the thickness of metal films and improved the understanding of time-dependent dielectric breakdown in thin silicon-dioxide films. These and other accomplishments are providing much needed help to U.S. semiconductor manufacturers who are constantly seeking better control, higher accuracy, and higher yields within their fabrication facilities.

The EEEL also provides standards for calibration of antennas and other wireless components. The availability of these standards, which have known error bounds and are traceable to national standards, has had a very positive impact on the international competitiveness of the U.S. telecommunications industry. The Laboratory's impact can also be gauged by the great industry demand for other services such as calibration services, by the level of industry participation in EEEL-sponsored training and workshops, and by the increasing commercialization of EEEL research through CRADAs and other forms of government/industrial cooperation.

Clearly, the impact of the EEEL's technical and scientific work has been most concentrated in sectors in which industries have clearly identified their needs for NIST services. An example of this is the semiconductor industry, which has explicitly stated its metrology needs in *The National Technology Roadmap for Semiconductors*, produced by the Semiconductor Industry Association, a major industrial effort to be further described by Dr. Jim Glaze who will follow me. Working afield from these successes, recent Laboratory efforts to assist other key industrial sectors in identifying their present and future needs show clear promise for expanding the role of the EEEL in supporting the metrology needs of those sectors.

As I previously mentioned, however, the EEEL continually faces challenges in choosing priorities in its program planning As part of its feedback process, the Panel has identified several areas where it thinks greater attention or improvement is merited in current and near-term EEEL programming. For example, the electric power industry is deregulating in a manner analogous to that of the telephone industry, and metering and measurements at various points in the power system will become much more numerous and important than at present The Laboratory's projects related to electric power are individually valuable and of high quality; however, in the view of the Panel, these EEEL efforts are having only minimal impact on industry. The Panel believes that the Laboratory is in a position to make important contributions if it can achieve the right focus, using its ties to industry players such as utility companies, independent power producers, and electrical equipment manufacturers to develop a roadmap of metering and measurement needs for the modern electric power industry, paralleling the efforts of the semiconductor industry.

Similarly, no coherent U.S industrial leadership exists in the development of international standards for commercial superconductors, and the Panel has recommended that NIST assume national leadership in this area Unfortunately, the present level of NIST staffing and support in this area is insufficient to compete effectively with a large competing Japanese effort If this level is not supplemented in the next year, the Panel has expressed strong concern that the result may be Japanese domination of the international standards in this critical area.

In another area of technology of major national importance, it has been clearly demonstrated over the past 20 years that many electrical measurements are best made at low temperatures. The collective impact on the capabilities of NIST in the metrology and standards arenas has been vastly enhanced by the low-temperature research of the EEEL at both its Boulder and Gaithersburg campuses Unfortunately, the current budget of the Boulder group appears to be frozen, resulting in the loss of one staff member per year. This is demoralizing a group that is a unique national asset. The Panel has recommended that a deliberate decision should be made at the Laboratory level to increase, maintain, or shrink these activities to an appropriate size, rather than letting it wither away

As American industries have learned over the past several decades, quality systems are important tools for improving measurement assurance, competitiveness, effectiveness of research and development activities, and the quality of goods and services. As with its industrial counterparts, the Panel has recommended that a documented or consistent quality system would increase the value of the Laboratory's calibration services to customers. The Panel has also recommended that EEEL should prepare for the effects of increasing ISO 9000 registrations within U.S. companies. The calibration requirements in this standards series are more stringent than those generally practiced by U.S. industry, and increasing ISO 9000 registrations will affect the Laboratory's workload and income from fees, and will also require continual improvement in these services.

The Panel's review of EEEL staffing has found some turnover in projects supporting fundamental standards, coupled with aging of the Laboratory staff and continued dependence on retired staff as consultants. The maintenance of fundamental standards is an exacting and unusual specialty, and in the opinion of the Panel, the Laboratory needs to attract qualified young scientists to ensure that the accumulated knowledge of the current staff is transferred to them as part of an orderly replacement and renewal process.

Despite facing the types of challenges common to most organizations at the present time, the Electronics and Electrical Engineering Laboratory is overall very well managed. Its staff is dedicated, and represents a significant resource for our nation. The Laboratory's technical programs are of very good to excellent quality, and its ties to its customers in industry are strong. In simple terms, the Panel has repeatedly found the EEEL to be a most effective national asset which is playing a key role in assuring U.S. competitiveness in the key electrical and electronics industrial sectors

Fiscal Year 1995 Assessment of the Electronics and Electrical Engineering Laboratory by the Panel for Electronics and Electrical Engineering

V. Thomas Rhyne, Motorola, Inc., *Chair*
B. Jayant Baliga, North Carolina State University
Gary M. Davidson, GM Davidson, Inc.
James F. Freedman, Semiconductor Research Corporation
H.R. Hofmann, AT&T Bell Laboratories
Roger F. Hoyt, IBM Almaden Research Center
James D. Huff, Scientific-Atlanta, Inc.
Richard I. Knight, Tektronix, Inc.
Frederick J. Leonberger, United Technologies Photonics, Inc.
Suzanne R. Nagel, AT&T Bell Laboratories
Arthur A. Oliner, Polytechnic University
Don Parker, Hughes Aerospace & Electronics Company
Alton D. Patton, Texas A&M University
D. Howard Phillips, Consultant, Durham, North Carolina
John M. Rowell, Conductus, Inc.
Robert E. Schwall, American Superconductor Corporation
Thomas J. Shaffner, Texas Instruments Incorporated
Horst L. Stormer, AT&T Bell Laboratories
Hugo Vifian, Harmonic Lightwaves
Owen P. Williams, Motorola, Inc.

Submitted for the panel by its Chair, V. Thomas Rhyne, this assessment of the fiscal year 1995 activities of the Electronics and Electrical Engineering Laboratory is based on site visits by individual panel members, a formal meeting of the panel on February 15-17, 1995, in Boulder, Colorado, and on documents provided by the laboratory.

LABORATORY OVERVIEW

Mission

The mission of the Electronics and Electrical Engineering Laboratory (EEEL) as stated in its program plan is

> to promote economic growth, and especially international competitiveness, by providing measurement capability of high economic impact focused primarily on the critical needs of the U.S. electronics and electrical-equipment industries. In fulfilling this mission, EEEL strives to provide leading-edge capability supportive of each of the major steps required to realize competitive products in the marketplace: research and development, manufacturing, marketplace exchange,

and after-sales support. Good measurement support is essential for accelerating the commercialization of technology, a primary requirement for improved U.S. competitiveness (*Electronics and Electrical Engineering Laboratory 1995 Program Plan* [NISTIR 5563], NIST, Gaithersburg, Md., pp. 1-2).

Resources

EEEL funding for fiscal year 1994 totaled $45.2 million; $29.4 million of this total was directly appropriated or STRS (Scientific and Technical Research and Services) funding; $3.0 million came from the Advanced Technology Program (ATP); $10.2 million came from external sources, mostly other government agencies (other agency or OA funding); and $2.7 million came from fees for calibrations and other services. Fiscal year 1995 funding was estimated at the time of this assessment to total $46.0 million, with $30.7 million from STRS, $2.1 million from the ATP, $11.1 million from OA, and $2.1 million from fees for calibrations and other services. Total staffing of 322 includes 283 full-time permanent employees, of whom 215 are technical professionals, 116 of whom hold a PhD degree.

The Priority-Setting Process

EEEL has used formal priority-setting methodologies as a means for selecting new projects for almost two decades. The current methodology has been in place since 1991. It assesses current and proposed projects against four criteria: fit to mission; potential impact if successful; probability of success; and impact on the institutional health of NIST, EEEL, and the EEEL staff. The objective of these multidimensional assessments is to focus available EEEL resources on the most appropriate set of technical projects. In addition, the EEEL priority-setting process allows for consideration of a limited number of project proposals that do not meet these criteria precisely but still offer the potential for outstanding technical or scientific value.

EEEL's written description of the current priority-setting methodology divides each of the four criteria listed above into more specific subcriteria. The "Fit to Mission" criteria, for example, includes assessment of the project's goals, customers served, deliverables, steps served within an associated manufacturing process, and uniqueness. The "Impact if Successful" assessment includes the criteria of market size, market immediacy, timeliness, criticality, sensitivity, visibility, and commitment.

In current practice, proposals for new projects are required to include detailed descriptions of the project versus the criteria and subcriteria defined in the EEEL priority-setting process. Reviews of new projects are normally conducted as part of EEEL's annual technical planning and budgeting activities, although opportunities are provided for initiating high-priority projects at other times if the assessment of such projects indicates opportunities for significant success and impact.

Assessment of Priorities and the Priority-Setting Process

The selection of projects within EEEL generally appears to be well matched to current industrial needs in the areas served by the laboratory. This assessment can largely be attributed to the effectiveness of EEEL's formal priority-setting process. Given limitations in available resources and the breadth and depth of need for advancement in the technical and scientific areas associated with the mission of the laboratory, however, continuous refinement of this process is essential to keeping EEEL in touch with its customers. With this goal in mind, the panel believes there is need for more involvement of and cooperation among the managers of all EEEL divisions in setting divisional and laboratory priorities

As an aid to evaluating year-to-year accomplishments, EEEL should report each year's accomplishments in relation to objectives and milestones for that year. Year-end reporting should identify goals that were accomplished as planned, goals that were not reached (and explanations), and additional accomplishments over and above the plan.

More specific comments regarding the effectiveness of project selection within the divisions and offices are provided in the divisional assessments below. Comments regarding the possible need for new projects or for the cessation of current ones can be interpreted as indications of the need for improvement in priority setting within that division. As the remainder of this report indicates, however, such instances are few, and the consensus assessment of the laboratory's priority-setting process was quite favorable.

Assessment of Technical Programs

The panel found EEEL's technical programs to be generally effective and competent. The laboratory's greatest challenge is to establish a strategy for acquiring new skills to respond to changing needs. Constant attention to better links between EEEL's Boulder, Colorado, and Gaithersburg, Maryland, groups is also needed More effective collaborations might be gained by increasing awareness of EEEL's competencies throughout all of NIST.

The panel was charged with reviewing EEEL's work with data programs. EEEL has not been active in NIST's Standard Reference Data (SRD) Program, although the Office of Microelectronics Programs (OMP) is sponsoring work in data for plasma etching and chemical vapor deposition modeling which may be distributed through the SRD Program in the future. EEEL has not been active in data programs primarily because the industrial community served by EEEL has not established such activities as a high priority. EEEL has independently responded to a limited number of highly specific requests for data, acting directly with interested commercial and governmental users. Participation in the SRD Program could enhance the availability of EEEL data collections and generate additional revenue to support or expand those activities. Any participation should be based on demonstrated need of EEEL customers for such resources. Specific examples of EEEL's independent data collection and distribution activities are given in the divisional assessments below.

Assessment of Impact on Industry

The panel identified numerous examples in which the work carried out in the laboratory during fiscal year 1994 resulted in measurable impact on one or more sectors of U.S. industry. As a general comment, however, the industrial impact of EEEL's technical and scientific work was most concentrated in sectors in which industries have identified their needs for EEEL's services. An example of this is the semiconductor industry, which has explicitly stated its metrology needs in *The National Technology Roadmap for Semiconductors* (Semiconductor Industry Association, San Jose, Calif., 1994; commonly known as the SIA Roadmap). Recent EEEL efforts to assist other key industrial sectors in identifying their present and future needs are quite appropriate and likely to improve the impact of EEEL work in those sectors. Specific comments on programs are provided in the divisional assessments below.

NIST's new Industry Fellows Program provides opportunities for NIST staff members to gain research experience in industrial settings, thus enhancing the technical and scientific qualifications of key NIST staff members while improving staff appreciation of industrial R&D operations. EEEL has played a key role in the development of this program and was one of the first NIST laboratories to participate in it. Three of four 1995 NIST industry fellows are EEEL staff members. The panel approves highly of this level of participation. The implementation of the NIST Industry Fellows Program is an outstanding success based on feedback from both industry and NIST participants. This program guarantees the ultimate partnership between NIST and its customers, and it should be expanded to smaller companies that are state-of-the-art performers in their field. Given the need for closer interactions between EEEL staff members and the industries that they serve, continued participation in this program appears to be an excellent way for EEEL to improve the quality of its technical and scientific activities.

Recommendations

The following are the panel's recommendations for EEEL as a whole.

- Working closely with customers in both industry and government, EEEL management should review data collection and distribution activities to determine the usefulness of participation in the NIST Standard Reference Data Program.

- EEEL should continue to aggressively pursue participation in the NIST Industry Fellows Program, including work with small, cutting-edge companies, and should consider reciprocal arrangements that can expand opportunities for engineers and scientists from industry to work at EEEL.

- EEEL should expand its activities to assist additional industrial groups in the electronics and electrical engineering sectors in defining their needs for metrology and related services, paralleling the work of the Semiconductor Industry Association in the SIA Roadmap.

- EEEL should seek ways to make its Gaithersburg and Boulder groups work more closely together.

- EEEL should seek to make the competencies of the laboratory better known and understood across all of NIST.

Electronics and Electrical Engineering Laboratory Responses to Fiscal Year 1994 Recommendations

Below are the panel's 1994 recommendations for EEEL as a whole, as quoted from the fiscal year 1994 assessment report, followed by the laboratory's response. The panel found these responses generally satisfactory

1994 Panel Recommendation: "EEEL technical management should conduct periodic reviews of fundamental research activities to verify that projects have a strong likelihood of benefiting the laboratory's mission and to identify new areas in which fundamental research is critically needed to provide sufficient measurement capabilities for advancing calibration and repeatability requirements. . . . " (p. 20).
Laboratory Response: NIST's role as the nation's premier measurements laboratory requires EEEL to remain at the forefront of electrical measurements, especially the measurement of basic electrical quantities. EEEL believes that maintaining a metrology leadership position is the best strategy for positioning to meet new calibration needs and paradigms, given that fundamental directed research projects are long-term affairs and that predictions of the future become more uncertain as the prediction time is extended

EEEL does conduct internal quasi-periodic reviews of all projects at about 3-year intervals; these include 5-year assessments of project plans. Each division provides 5-year plan charts of its projects as part of its annual *Program Plan*. Also, laboratory management maintains a general oversight of project activity through internal reporting mechanisms and as a result of preparing the *Program Plan*. Individual projects are reviewed on an ad hoc basis in order to resolve specific issues; EEEL will consider conducting a specific strategic review of fundamental directed research projects in calendar year 1995

1994 Panel Recommendation: "Procedures for assigning technical work to divisions should be reviewed to assure that work is assigned most appropriately. Efforts to align the divisions' strengths more closely with the global EEEL mission should continue" (p. 20)
Laboratory Response: EEEL has developed and promulgated among its staff guidelines for project selection. There is a shift away from projects that benefit primarily other agencies. However, many OA projects undertaken in EEEL have been and are in pursuit of goals aligned with the EEEL mission, one of NIST's responsibilities is to assist other agencies with respect to metrology, and OA projects are a means to keep in contact with advanced developments. Implementation of the panel's suggestion to extend strategic planning more explicitly to the division level will contribute to a more integrated laboratory structure.

1994 Panel Recommendation: "EEEL should identify less organized sectors of the U.S. electronics and electrical engineering industry, which seem of critical importance to U.S. competitiveness, and provide support of leadership in identifying their metrology needs" (p. 20).

Laboratory Response: Measurements for Competitiveness in Electronics (NISTIR 4583, U.S. Department of Commerce, 1993) is intended to provide a vehicle through which EEEL can identify principal measurement needs. A number of significant technical areas remain to be addressed. Some of these potential constituencies will be disaggregated in nature and lack a cohesive voice, akin to the situation experienced with much of the industry providing measurement instrumentation. Widespread participation by EEEL staff in conferences, professional societies, standards organizations, and trade associations helps the laboratory to be aware of needs.

1994 Panel Recommendation: "As NIST's resources increase, EEEL should be proactive in obtaining resources for work in basic measurements and R&D of critical importance to the U.S. electronics and electrical engineering industries" (p. 20).
Laboratory Response: Obtaining resources for such work is part of budgetary initiatives under development for fiscal year 1997 and was considered as part of unsuccessful initiatives for fiscal year 1996. In addition, EEEL has sought and been awarded competence funds; three such projects are active in fiscal year 1995.

1994 Panel Recommendation: "EEEL staff should review current policies regarding support of non-U.S.-owned industries, since the technical needs of foreign-owned companies may be of critical importance to industrial developments in the United States and to agreement between U.S. standards and measurements and those of international trading partners and competitors" (p. 20).
Laboratory Response: This matter is beyond EEEL control. Formal restrictions deriving from statute state that a foreign-owned company must certify that it is "incorporated under the laws of one of the states or territories of the United States; and that it has a manufacturing presence in the United States; and that the foreign government [involved] permits United States agencies, organizations, or other persons to enter into cooperative agreements and licensing agreements." EEEL has entered into a Cooperative Research and Development Agreement (CRADA) with at least one foreign-owned company that satisfied the restriction.

1994 Panel Recommendation: "Opportunities exist for more complete utilization of the Baldrige Award criteria in laboratory planning and execution. The panel found no consistent use of such a system within NIST, although some efforts have begun; EEEL has no strategic plan to put such a system in place" (p. 20).
Laboratory Response: Complex issues are involved in applying the criteria to a research and development organization. In EEEL, the Electricity Division serves as a pilot for the laboratory and formed a team drawn from all levels to investigate quality issues. This past year, following visits to a number of firms to see total quality management (TQM) in action and to discuss the application of TQM principles, the division hired a consulting organization that has conducted interviews with division staff. The division is now evaluating feedback from the interviews to decide the next steps.

1994 Panel Recommendation: "EEEL should leverage resources through targeted participation in ATP proposals. This effort can also help organize industrial participation in key areas of technology development" (p. 20).

Laboratory Response: Guidance recently issued by the NIST director states that "NIST personnel should not be involved in ATP proposal preparation and should not critique applicants' proposals." The same guidance states that "technical collaboration with awardees is encouraged," under the provisions of a CRADA. EEEL has established CRADAs with several ATP awardees and will continue to pursue participation in CRADAs with awardees when there is a mutual benefit.

1994 Panel Recommendation: "EEEL management and NIST human resources personnel must maintain the strength of the technical staff as the role of EEEL shifts away from some long-term OA customers and their specialized technical requirements. Appropriate retraining opportunities should be provided for displaced staff, and staff with new capabilities must be recruited" (p. 20). *Laboratory Response:* In fiscal year 1994, almost one-third of the staff participated in some 216 courses; many of these individuals are professionals, and of these, a number were extending their areas of competence to meet new metrology needs from industry. Also in fiscal year 1994, EEEL hired 27 persons, including a number of well-qualified professionals to strengthen staff skills in new areas.

DIVISIONAL ASSESSMENTS

Electricity Division

Mission

The Electricity Division provides the fundamental basis for all electrical measurements in the United States. The division supports U S. industry by providing electrical measurements and standards infrastructure required to develop new products, ensure quality, and compete internationally.

The division realizes the electrical units in terms of the International System of Units (SI) and determines fundamental constants related to electrical units. The division is responsible for providing calibration services and developing and improving the measurement methods and services needed to support electrical materials, components, instruments, and systems used for conducted electrical power, industrial electronics, and electronic-related products and services. The division is responsible for facilitating the design, manufacture, documentation, procurement, and application of electronics systems by supporting development of product data exchange standards and specifications. The division is also responsible for the development of measurement technology to support electronic imaging and video products.

Resources

The division's fiscal year 1994 funds totaled $10.3 million, comprising $5.7 from STRS, $0.8 million from ATP, $1.2 million from fees for calibrations, and $2.6 million from OA. Fiscal year 1995 funding was estimated at the time of the assessment to total $10.7 million: $6.5 million from STRS, $0.7 million from ATP, $1.2 million from calibrations, and $2.3 million from OA. Of a total paid staff of 80, 54 are technical professionals and 24 hold a PhD degree.

Assessment of Priorities and the Priority-Setting Process

In most areas, the prioritization of the division's projects is in concert with industry requirements. Participation in industry associations and industry visits and involvement in international activities have provided the division with a solid sense of industry needs for standards and calibration. However, the program in electric power is experiencing a general decline in funding, and the research planned in this area seems disjointed and suffers from a lack of industry visibility and direction, even though this is a time of great potential opportunity.

The prioritization process seems to deal best with evolutionary programs. Program plans in new areas, such as video technology and automated electronics manufacturing, reflect a significant disparity between stated goals and the resources actually provided to achieve these results.

Assessment of Technical Programs

The panel found the technical quality of the division's programs to be consistently good. In some cases (for example, the Video Technology project and the Automated Electronics Manufacturing project), resources were quite limited compared with the technical objectives. Careful prioritization is required in these areas, and perhaps a reduction in stated objectives should be considered. Resources could become an issue in the Measurements to Support Electric Utilities project as well, if tighter linkages with industry result in an expansion of program goals. Some turnover is being experienced in this division, and aging of the staff and continued dependence on retired staff are concerns, especially in the area of fundamental standards. Maintenance of fundamental standards is an exacting and unusual specialty; EEEL needs to attract qualified young scientists and ensure that accumulated knowledge is transferred to them as part of an orderly replacement and renewal process. The division has continued to demonstrate the ability to provide the fundamental metrology capabilities that are its mission and to develop new technology and enhanced capability in these areas. The following comments on key projects illustrate this balance.

The Generation and Measurement of Precise Signals project and the Improved Impedance Calibration Service project are closely coupled. Progress over several years has replaced antiquated measurement systems with modern technology that provides enhanced capability. For example, a newly developed digital impedance bridge has allowed the first significant improvement in inductance measurements in 40 years. This new technique for measurement of inductance will also lead to reduced uncertainties in the generation and measurement of precise signals. Based on this advance, as well as on improvements in the binary inductive voltage divider, digital synthesis, and other measurement technologies, decreases in uncertainty by factors of 10 or more are targeted for calibration services for capacitance, inductance, and loss.

The AC/DC Difference Standards and Measurement Techniques project may soon provide industry with thermal transfer standards that are nearly as precise as the national standard. These thermal transfer standards are necessary in measurement of electric power, energy, alternating current (ac) voltage, and ac current. The existing national standard is inadequate to calibrate the transfer standard over its full range. In conjunction with the Semiconductor Electronics Division and the Electromagnetic Technology Division, cryogenic phenomena are being used to develop a new thermal converter with sensitivity approaching the quantum limit, extending the range and uncertainty of the current national standard The division shared an R&D 100 Award with the Semiconductor Electronics Division and Ballantine Laboratories (Cedar Knolls, N.J.) for work in this area, and the importance of this project to industry is reflected by the large number of CRADAs relating to this work. However, lack of staff has caused slower than desirable progress on this project.

The Resistance Standards and Measurement Methods project continues with a high rate of success. Two technological improvements—a guarded scanner under development in industry with NIST support, and implementation of an active-arm bridge (following the approach of the U.K. National Physical Laboratory)—may lead to automation of high-resistance measurements and may extend these measurements to wider ranges. This capability is needed by industry, which requires accurate resistance measurements for quality and process control purposes. It will be of particular importance to the semiconductor industry to support the reliable and inexpensive testing of nonfluorocarbon solvents used in processing.

The Waveform Acquisition Devices and Standards project also continues to improve capability in line with evolving industry requirements, addressing characterization of the performance of the most demanding waveform sampling systems across a broad range of speeds and resolutions. Results from this program are delivered in the form of measurement services and in the development and transfer of useful measurement standards and measurement techniques. An ongoing challenge is the creation of new capabilities for generating and characterizing picosecond pulses. The YAG laser technique demonstrated during fiscal year 1994 has presented technical issues that suggest this may not be the optimum technology to pursue. An important objective for the coming year should be completion of a technological assessment of this and alternative approaches and selection of a technology for implementation. This is especially important, since NIST capability does not now provide a comfortable safety margin when compared with the emerging requirements within industry.

The Measurements for Complex Electronic Systems project has led to techniques for modeling complex measurement acquisition systems that offer promise for simplifying industrial manufacturing test processes and significantly reducing test costs. Two companies actively benefit from this technology, and others are considering the approach. Ongoing efforts to reduce this technology to a set of software tools attuned to the needs of industrial users are a critical step in deriving the maximum benefit from this work.

The Quantum Voltage and Current project and the Quantum Resistance and Capacitance project provide the required legal basis for virtually all electrical measurements in the United States Major developments in the recent past such as Josephson array voltage standards and resistance standards based on the quantum Hall effect have made positive contributions to NIST's worldwide reputation. Current work on the ac quantum Hall effect could lead to a primary impedance standard that is more readily usable for calibrations than the current standard. However, the priority of work on both ac and direct current (dc) quantum Hall effects relative to other potential projects should be reviewed to assure maximum impact by these researchers. Single-electron tunneling (SET) research ongoing in both Boulder and Gaithersburg provides a valuable link between lithographic techniques and primary standard development. This research could lead to a current source directly derived from a frequency standard, increasing the accuracy of such standards by allowing intercomparison with current sources based on the Josephson effect and the quantum Hall effect. Although earlier duplication of efforts at the two sites has been resolved, management must give continual attention to keeping each location focused on its primary areas of competence. Efforts to develop an "electronic kilogram," that is, a standard for the kilogram based on electronic properties which would replace the current artifactual standard, have been recognized with NIST competence funding. EEEL should regard this work, which would advance the kilogram standard to an accuracy of about 1 part in 10^7 or possibly 10^8, as a primary challenge and complement the competence funding with requisite instrumentation and personnel support.

The Measurements to Support Electric Utilities project has adequate staff and facilities to meet its current objectives but should consider addressing a wider range of utility industry needs. Current work in the areas of watt-hour standards, calibration of optical current transducers, and reference measurement systems for high-voltage testing is traditional, appropriate, and of high value to industry. The division's work in development of accurate methods for measuring low-frequency electric and magnetic fields is extremely important and relevant to industry needs; here NIST is performing a vital and unique service. Ongoing work in surge protection technology is of high quality, but duplicates work being performed outside of NIST and does not seem central to the mission of the division. A growing issue for industry is revenue metering in the face of increasing waveform distortion brought about by switching power supplies and other nonlinear loads. In general, measurement and characterization of distorted waveforms is, and should be, a future priority for the division.

Work in the Dielectrics Research project studying the generation of toxic gases in SF_6-insulated high-voltage circuit breakers has been important in laying to rest concerns in this area. As a related follow-on, work on use of partial discharge data in predicting insulation condition is important. However, a much better connection to industry and domestic equipment manufacturers should be developed if this work is to be continued. Also, related efforts are ongoing at a number of other institutions, making the uniqueness of NIST's contribution and capabilities in this area open to question

The Video Technology project has a stated objective of two distinct but related goals: developing metrology for flat panel displays and developing measurements for assessing video quality and interoperability. Unfortunately, the resources of this team do not appear to be sufficient to meaningfully address both of these areas. The practical result of this has been a convergence within the group on work primarily addressing flat panel displays and display-related perceptual effects. This work is appropriate and should continue. However, it is questionable whether the group can address video measurements effectively and whether a window of opportunity still exists for the division to contribute meaningfully in this area.

As noted in the fiscal year 1994 assessment, the Automated Electronics Manufacturing project appears to be critically understaffed, and competition for resources to support work on product data standards is being won by other NIST laboratories. In the absence of a significant infusion of resources, this project should be discontinued, and work on product data standards for electrical and electronic products shifted to the Manufacturing Engineering Laboratory, which has a significant program in exchange of product data. NIST's role in this area is appropriate, and these efforts should include close work with U.S. electrical and electronic industries, but a subcritical effort within this division does not appear to be an appropriate use of EEL's resources.

Assessment of Impact on Industry

The technical programs of the division are having a positive impact on industry, as evidenced by the use of calibration services and industry participation in training and workshops and in the commercialization of research through CRADAs and other forms of cooperation. An additional indication of impact on industry has been the creation of a Digital Video ATP project in response to industry needs identified in a NIST workshop. In the future, the division's industrial customer base may be expanded to include users and manufacturers of flat panel displays as work in this area matures. However, some areas provide opportunity for improving impact on industry, as discussed below.

Quality systems are used in industry to improve measurement assurance, competitiveness, effectiveness of research and development activities, and the quality of goods and services. No such consistent system exists within NIST. The Electricity Division, although part of a pilot program for use of quality systems within NIST, lacks a documented or consistent quality system and has not shown significant progress in this area since the previous assessment.

New intrinsic standards are being developed, and the use by industry of existing intrinsic standards is expanding. These intrinsic standards are complex and, when not properly operated, give rise to significantly erroneous results. A measurement assurance system needs to be developed to preclude degradation of the U.S. measurement system. The division should also develop plans to further address industry's needs for seminars, workshops, and publications in the areas of intrinsic standards, measurement assurance, and measurement techniques.

A calibration laboratory accreditation program is now offered by NIST. To be of maximum value, the NIST accreditation program must be accepted internationally. Such acceptance requires identification and resolution of technical issues related to differences in other national programs, such as development of a formal quality system for calibration services, specific methods of developing traceability through scaling, and formal coordination of basic standards.

Industry users find turnaround time for NIST calibration services excessive. The division should review operating processes to identify opportunities to reduce this cycle time. In addition, thorough planning must be done in advance of planned facility moves to avoid disruption of these vital services to industry.

The division should plan for the effects of increasing International Organization for Standardization 9000 series (ISO 9000) registrations. Calibration requirements in this standards series are more stringent than those generally practiced by U.S. industry. This increase will affect the division's workload and income from fees and will also require continual improvement in these services.

The electric power industry is entering a period of great change. As the industry deregulates in a manner analogous to that of the telephone industry, metering and measurements at various points in the system will become much more numerous and important than at present. The division now has an opportunity to assist in creating needed metering and measurement methods and standards. This is all the more important because of the changing status of the

Electric Power Research Institute (EPRI). Division projects related to electric power are individually valuable and of high quality. However, because of lack of focus, these projects seem to have minimal impact on industry. The division is in a position to make important contributions if it can achieve the right focus and coupling to industry. The division should use its ties to industry players such as EPRI, the Edison Electric Institute, the American Public Power Association, the Federal Energy Regulatory Commission, utility companies, independent power producers, and electrical equipment manufacturers to develop a roadmap of metering and measurement needs for the modern electric power industry. The division should then develop projects based on that roadmap to establish and maintain its technology flow to industry.

Recommendations

The following are the panel's recommendations for the Electricity Division.

- The Electricity Division needs to attract qualified young scientists and to ensure that accumulated knowledge, particularly in fundamental standards, is transferred to them as part of an orderly replacement and renewal process.

- The division should devote sufficient technical effort to development of picosecond pulse standards to ensure identification of a technology path for short pulse measurement.

- The division should resolve the inconsistency between program goals and resources in the Video Technology project.

- A consistent quality system should be developed within the division to assure the quality and effectiveness of services delivered to industry and of research and development activities.

- The division should develop plans to ensure the integrity of intrinsic standards and their use.

- The division should address the potential impact of increasing ISO 9000 registrations and calibration laboratory accreditations. This should include addressing the needs of U.S. industry for international recognition of calibrations performed in the United States.

- The division should review its calibration services to reduce cycle time and avoid disruption of service during facility relocation.

- The division should use its ties to key players in electric power to determine a more focused program to serve that industry.

Electricity Division Responses to Fiscal Year 1994 Recommendations

The panel's 1994 recommendations for the Electricity Division, quoted from the fiscal year 1994 assessment, and the division's response are given below. The 1995 panel was disappointed in the division's responses to these recommendations, finding them somewhat defensive rather than responsive.

1994 Panel Recommendation: "The Electricity Division's mission statement should mention fundamental goals of its work and, since it does not currently include the entire scope of the division's responsibilities, should be written with a wider focus" (p. 25).
Division Response: The mission statement was rewritten with broader scope.
1995 Panel Comment: The mission was appropriately modified as recommended. However, it is questionable whether the division has the resources to fully discharge this mission, especially as it relates to video and to product data exchange. It may be appropriate to reduce the scope of the mission in these areas.

1994 Panel Recommendation: ". . Changes in the structure of the electric utility industry and its research arm, the Electric Power Research Institute (EPRI), provide a window of opportunity enabling the division to serve this industry's needs by (1) broadening activities to provide services to new players and stakeholders in the power industry . . . (2) improving technology transfer to the industry . . . (3) widening the use of collaborative arrangements with the industry; and (4) developing new customers for metrology services such as independent power producers and large industrial customers" (p. 25).
Division Response: The division is addressing these problems and opportunities by attempting to direct the electric power-oriented portion of its research program to areas that most critically benefit the industry. The ongoing reorganization of the division allows a more focused effort to be applied; specifically, the newly formed Electrical Systems Group will concentrate most of its resources on utility-related problems. However, limitations in funding, and the lack of a clear determination of the metrological needs of the electric power industry, will continue to restrict support to this industry. In an attempt to determine industry needs, division and laboratory management will be visiting industry representatives. Different approaches to technology transfer, such as technical workshops and collaborative agreements, are being taken to supplement the traditional publication of results.
1995 Panel Comment: The division has not adequately addressed this issue. The division should use its ties to key players in electric power to determine a more focused program to serve this industry.

1994 Panel Recommendation: "The panel recommends that non-U.S.-owned equipment manufacturers have access to research results, since such research would be used to develop, aid, or improve technology in U.S. plants" (p. 26).
Division Response: Placing limitations on access to NIST results by non-U.S.-owned companies is a policy issue beyond the division's control. However, nearly all of the division's output is published in the open literature.

1994 Panel Recommendation: "The division should establish programs in areas in which it can play a valuable role, such as . . . energy efficiency . . . electromagnetic fields . . . power quality . . . distribution and transmission systems . . . environmental impacts of the utility industry; and . . . industry . . . benchmarking standards" (p. 26)

Division Response: The division has begun a program funded by the Department of Energy (DOE) to review test procedures and specifications for energy-efficient motors and transformers. The division's experimental program in metrology of electromagnetic fields continues essentially unchanged from previous years. The power quality program continues to be effective in educating utilities and industries in the complex area of power quality; no calibration services are being planned at this time. The division continues to develop its program to provide metrological support of optical sensors for electric power transmission and distribution systems. Benchmarking of measurement practices used in the power industry would require resources considerably beyond those of the division at present. Experience elsewhere in EEEL has shown that the selection of a standardized set of measurement parameters and the subsequent evaluation, analysis, and selection of a set of methods for determining those parameters are complex processes requiring staff-years of effort even when the field is narrowly defined

1994 Panel Recommendation: "Techniques being developed by the division for measurements in complex electronics systems are ready for practical application and ready to be assessed for obstacles to implementation and economic and technical benefits The division should consider technology transfer to a target group of early users and should conduct a technical and economic analysis of the results. . . ." (p. 26).
Division Response: Efforts to transfer information on testing strategies and principles have continued by visits by the technical staff to various instrumentation and semiconductor device manufacturers, the hosting of the third "Testing Strategies for Analog and Mixed-signal Products Workshop," and the initiation of development of a user-friendly software tool for implementing the matrix operations needed to develop testing strategy. Analog Devices (Wilmington, Mass.) is adopting the NIST testing strategies for its data converter products. That company's economic assessment thus far shows a projected annual savings of $400,000 on the production testing of two of its 16-bit converter products and a cost reduction of several million dollars per year if this approach can be broadly applied to its converter product line. In addition, software based on NIST testing strategies is marketed by a major manufacturer of semiconductor device test equipment.

1994 Panel Recommendation: "At this early stage, work on metrics for video quality can benefit from defining the problems that this project will address. Particular attention should be given to quality metrics required for successful creation and operation of video for the NII [national information infrastructure], and how the proposed metrics will be employed by industry" (p. 26).
Division Response: A needs assessment for video quality metrics associated with compression techniques is being conducted through review of published literature, telephone conversations with industry representatives, and site visits to selected laboratories. This assessment will identify specific observable artifacts deemed critical by industry which can be quantified, so the resultant metric can be used in part to define quality. The division organized a workshop attended by 187 industry and government representatives to discuss the role of digital video within the national information infrastructure.
1995 Panel Comment: Defining and staffing the program in video have not been adequately addressed. At this time, it still appears that the stated goals and the amount of staff assigned are incompatible.

1994 Panel Recommendation: "Resources allow the division an expanded role in measurement applications. This will require closer linkage to industrial applications and partners in order to identify requirements and manage the transfer of technology, faster time frames in order to meet industry requirements and match the rate of change of industrial technology, and establishment of new technical competencies as required by targeted measurement applications" (p. 26)
Division Response: In fact, the division finds itself resource limited. In particular, anticipated funding to support new areas such as the Video Technology project and the Automated Electronics Manufacturing project has not been allocated. In all work, the division strives to respond in a timely fashion and to develop the necessary competencies to meet the needs of customers.

1994 Panel Recommendation: "EEEL should ensure that the Automated Electronics Manufacturing Program receives the 1995 resources needed to accomplish its strategic plans" (p. 26).
Division Response: Division and laboratory management are addressing funding for the Automated Electronics Manufacturing Program (AEMP). An increase in base funds was sought in the fiscal year 1995 and 1996 initiative development process, but in each instance AEMP was not selected for funding. An increase for AEMP is again being sought in the fiscal year 1997 initiative process. The AEMP will be getting only a small fraction of the money originally budgeted for fiscal year 1995. This has significantly impacted the ability of the AEMP to meet identified needs of the electronics industry.

1994 Panel Recommendation: "The division should continue its thrust in high-speed instrumentation, establishing ultraprecise and ultrahigh-speed pulse measurement capability. Optoelectronic/electro-optic technology is the best choice to provide absolute performance beyond commercial systems. The division should pursue further development in this area with the goal of characterizing the best commercial and developmental waveform sources and acquisition systems" (p. 26).
Division Response: Present efforts are aimed at reducing the uncertainties in measuring fast pulse sources with transition durations down to 15 picoseconds and sampling systems with bandwidths up to 20 GHz. The research exploits optoelectronic means for generating fast electrical pulses that can be used to characterize the impulse response for the 20 GHz bandwidth sampling systems currently used for supporting the NIST fast pulse calibration services. The division intends to extend this effort to find ways for supporting state-of-the-art 50 GHz bandwidth sampling systems, using optoelectronic means, electro-optic methods, nonlinear planar transmission lines, or a combination of all three technologies. At the same time, the division is developing sampling comparator-based waveform acquisition systems that are highly accurate for characterizing the settling performance of the best commercial data converters and precision waveform sources.
1995 Panel Comment: The division has made a commitment to create a picosecond pulse measurement capability as recommended. The technology path has proven more difficult than anticipated a year ago, with the result that absolute progress is less than expected. Focus should be maintained, with an initial goal of selection of an appropriate technology. The alternative technologies now being considered may be more suitable to replication and transfer to users in industry.

Semiconductor Electronics Division

Mission

The Semiconductor Electronics Division develops and evaluates measurement methods, data, reference artifacts, models and theory, and associated technology to remove market barriers associated with the use of semiconductor materials and with the design, fabrication, characterization, and performance assurance of semiconductor devices and integrated circuits; conducts research in semiconductor materials and processes, devices, and integrated circuits to provide, through both experimental and theoretical work, the necessary basis for understanding measurement-related requirements in semiconductor technology; and disseminates and fosters application of technical results and assists in the development of standardized test methods and Standard Reference Materials (SRMs) to enhance the quality, performance, and reliability of semiconductor materials, devices, and integrated circuits to aid in manufacturing productivity and in the development, transfer, and exploitation of semiconductor technology for public benefit.

Resources

Total fiscal year 1994 funding of the Semiconductor Electronics Division was $8.03 million, comprising $5.97 million from STRS, $0.78 million from ATP, $0.09 million from fees for SRMs, and $1.19 million from OA. Fiscal year 1995 was estimated at the time of the assessment to be $9.04 million total: $7.65 million from STRS, $0.44 million from ATP, $0.06 million from SRM fees, and $0.89 million from OA. Total staffing is 51.2 full-time equivalents; of these positions, 34.8 are technical professional. Of 42 technical professional staff members, 25 hold a PhD degree.

Assessment of Priorities and the Priority-Setting Process

The panel found it difficult to assess the effectiveness of the prioritization process in this division because no major new projects were initiated or terminated since the previous assessment, although some new tasks were added to existing projects. As best identified, however, divisional priorities seem to favor future technologies and core competencies. It appears that the prioritization between work in the key areas of compound semiconductors and silicon "shrink" technology has been applied in a fairly informal fashion, especially considering current expertise within the division, available facilities, interests of current personnel, and known interests of potential customers. Also, the division's mission statement does not convey the full breadth of its role. In particular, the trend toward integration and the division's programs addressing that trend are not reflected; neither are the division's unique metrology capabilities for measuring materials and material parameters for customers.

Assessment of Technical Programs

The Nanoelectronics project responds to needs identified in the SIA Roadmap for measurements on the scale of 10 to 100 nm. The project's emphasis on shallow junction dopant profiling with less than 10 nm spatial resolution is appropriate, for without this capability, engineers must resort to trial and error based solely on electrical test data to verify fine line design and the integrity of new processes for manufacturing submicrometer structures. Work towards these goals using scanning capacitance microscopy is world class, well equipped, and in direct support of EEEL's metrology mission Development of techniques for in situ diagnostics during molecular beam epitaxial growth of semiconductors is also within the metrology charter, but this motivation does not seem to be at the heart of ongoing investigations of growth kinetics within this project. The division's fundamental studies of these materials seem to duplicate activities in industry and universities, and sensor accessories seem peripheral to the ongoing work. Justification for work on compound semiconductors is also unclear; this portion of the project seems to rely heavily for guidance on the SIA Roadmap, which does not deal explicitly with compound semiconductors. In the absence of other guidance, selection of materials systems for study appears more by circumstance (such as an existing competency, customer involvement, or available funding) than by strategic intent Work with x-ray techniques (diffraction, reflection, fluorescence) for in situ monitoring does fill an existing void for both silicon and compound semiconductors. However, the division needs to ensure vendor involvement during development so that tools of the most practical value become commercially available; the extent of this activity needs to be tempered by the relatively small market for such equipment.

The division's description of the needs addressed by the Semiconductor Characterization project covers applications extending from digital circuits for computers to emitters for optical communication. This area is extremely broad Of the nine programs within the project, four relate to both silicon and compound semiconductors, two to the development and certification of SRMs, two to future silicon devices, and one to a survey to identify industrial requirements for techniques and related reference materials Considering the current problems in silicon device characterization in the 250 to 100 nm range, it is surprising that no programs address these needs. The panel questions this and urges reassessment of program priorities In addition, progress and industrial impact might be increased if this work were organized according to industry needs being addressed, for example, into programs on silicon semiconductor characterization for logic and memory and on compound semiconductor characterization for optoelectronic communications

The goals of the Electrical and Thermal Characterization project have been well articulated to provide support for the development of computer-aided design tools, specifically electrical, thermal, and mechanical models for semiconductor devices and packages, as identified by the SIA Roadmap. The technical approach to be taken—developing the theoretical foundations, standards, model validation procedures, and experimental techniques for measurement of chip and package temperature and electrical and thermal characteristics—is sound.

The goals of the Thin Film Characterization project are twofold: establishment of metrology tools for evaluation of robust gate dielectrics at a thickness range of 5 to 200 nm, and development of low-cost silicon-on-insulator (SOI) substrates. The first goal is aligned with the SIA Roadmap, and the second is motivated by the need to support an Advanced Research Projects Agency (ARPA) low-power electronics initiative The technical approach is to develop

SRMs and transfer this technology to industry with traceability to NIST, following a proven track for success.

Current program plans for thin oxide films are consistent with the metrology mission. The commitment to developing SRMs in the range of 10 to 200 nm to be produced by industry with NIST support is a timely response to the needs of the semiconductor industry.

The Test Structure Metrology for Advanced Semiconductor Manufacturing project seeks to provide domestic semiconductor manufacturers with improved test structures, test methods, and diagnostic procedures, allowing U.S. companies to manufacture competitive, cost-effective semiconductor products. The project's current work on improved methods for measuring linewidths and feature placement, for developing sensors for improved process control in the manufacture of interconnects and oxides, for improving measurements associated with micro-electro-mechanical systems (MEMS), and for improving tool performance through better gas sensor arrays are appropriate to the mission of the division. Plans to improve linewidth measurements (a collaboration with the Manufacturing Engineering Laboratory), to evaluate contactless measurements of capacitance and inductance from chemically and mechanically polished interconnect levels, to better characterize time-dependent dielectric breakdown (TDDB) of 9 and 15 nm oxides under electrical stress (a collaboration with the National Semiconductor Corporation), and to undertake other projects including collaboration with other companies and government agencies also align with the needs identified in the SIA Roadmap.

Assessment of Impact on Industry

Accomplishments and impact since the previous assessment in the Electrical and Thermal Characterization project were primarily in the area of power devices and power integrated circuits. These results are of importance to the power electronics industry both from the component supplier side and the user side. This work also provides a valuable service to the sizable industry involved with appliance controls, heating/ventilating/air conditioning, factory automation controls, and the nascent electric vehicle technology. Its impact can be measured on the basis of strong industry participation in NIST-sponsored workshops on model validation and the interactions with industry via the CRADA and ATP programs.

Accomplishments since the previous assessment in the Thin Film Characterization project include the demonstration of interlaboratory capability for thin film oxide measurements to meet the requirements of the SIA Roadmap and the development of the first 10 nm oxide thin film SRM in response to industry requests. These milestones are important and demonstrate the effective industrial impact of this project. The impact of this project is also evident from the transitioning of SRM technology to industry to meet the requirements of the SIA Roadmap.

Since the previous assessment, the Test Structure Metrology for Advanced Semiconductor Manufacturing project demonstrated the dynamic precision of electrical overlay test structures to be 1.5 nm, improved understanding of TDDB in thin silicon dioxide films, refined methods of electrically measuring the thickness of metal films, and fabricated and tested a large area MEMS thermal display. These and other accomplishments, including several patents granted within this projects, offer much needed help to U.S. semiconductor manufacturers seeking better control, higher accuracy, and higher yields within their fabrication facilities.

Recommendations

The following are the panel's recommendations for the Semiconductor Electronics Division.

- The Semiconductor Electronics Division should revise its mission statement so that it more accurately reflects the division's role and services.
- The division should consider separating its work on semiconductor characterization according to industry needs served.

Semiconductor Electronics Division Responses to Fiscal Year 1994 Recommendations

The panel's 1994 recommendations for the Semiconductor Electronics Division are given below, quoted from the fiscal year 1994 assessment report, with the division's response. The 1995 panel was, in general, somewhat disappointed in the division's response to these recommendations.

1994 Panel Recommendation: "The panel reiterates its fiscal year 1993 recommendation that the Semiconductor Electronics Division take leadership in formulating with industry a national strategic plan for compound semiconductors" (p. 31).
Division Response: The division has actively participated in the development of the second edition of the National Technology Roadmap for Semiconductors for silicon technology and has initiated a process to address strategic planning for compound semiconductors. The first major activity in this endeavor, "Satellite Workshop: Planning for Compound Semiconductor Technology," was held in conjunction with the "International Workshop on Semiconductor Characterization. Present Status and Future Needs." Participants, in addition to NIST, included the Optoelectronics Industry Development Association, ARPA, the National Electronics Manufacturing Initiative (of the Electronics Subcommittee, Committee on Civilian Industry and Technology, National Science and Technology Council), and other industrial technologists.

1994 Panel Recommendation: "NIST, with the support of the SIA Roadmap Coordination Group, is establishing a Semiconductor Metrology Advisory Group composed of government, industry, and university interests and equipment suppliers. NIST should use this advisory group to establish priorities for the metrology needs expressed in the renewed SIA Roadmap" (pp. 31-32)
Division Response: This advice would lead to complications involving the Federal Advisory Committee Act. The division concurs that it is essential for NIST to have more information on the industry's metrology needs than the SIA Roadmap can provide. Ways of accomplishing this goal have been developed with the cooperation of the SIA Roadmap Coordination Group, but details of implementation are still being worked out.

1994 Panel Recommendation: "In response to OA funding, the division often undertakes research that falls outside its primary metrology mission. The format for the division's program

plan should be changed to relate each project activity clearly to its funding source, thereby facilitating a better assessment of project objectives and accomplishments in relation to the appropriate strategic mission" (p. 32).
Division Response: The division does not generally take on OA assignments without a metrology component. All current internally and OA-supported activities meet the EEEL criteria for project selection. Funding sources are listed in the division's program plan.
1995 Panel Comment: Although the division states it does not take on OA assignments without a metrology component, the panel still concludes that several current OA projects (such as projects on micromachined semiconductor devices and separation by implanted oxygen material development) fall outside the primary metrology mission and strongly urges that all OA projects be measured by the same criteria as the STRS projects.

1994 Panel Recommendation: ". . . [Projects] that were supported under OA funds must be evaluated to assure that their objectives can be clearly related to the strategic metrology mission of the division before STRS funds are applied to them. Examples of projects that need reevaluation are the silicon-on-insulator effort and model development for commercial software" (p. 32).
Division Response: The SOI effort has in the past responded mainly to OA needs, one of NIST's responsibilities, and is still largely supported by funds transferred from other agencies, even though its use in the commercial arena for future circuits seems to be increasing. The SIA Roadmap acknowledges that the development of low-cost SOI substrates would advance integrated circuit performance a full generation.

The SIA Roadmap identifies integration of component-level electrical, thermal, and mechanical models for semiconductor devices and packages, and the availability of calibrated and easy-to-use technology-computer-aided-design tools for device, process, and circuit simulation as areas requiring development and support to achieve the 15-year goals of the Roadmap. The division addresses these needs by developing the theoretical foundations, standards, model validation procedures, and associated experimental techniques for the measurement of chip temperature, device electrical and thermal characteristics, and package electrical and thermal characteristics.

The division is developing with industry procedures for validating device models for circuit simulation. NIST is also developing procedures for characterizing the thermal and electrical performance of advanced integrated circuits and devices and the associated electronic packages that are compatible and useful for computer-aided design of boards and systems.
1995 Panel Comment: The panel feels that the division's response misses the key point of the recommendation.

1994 Panel Recommendation: "Because of rapid changes in the metrology needs of the semiconductor industry, the division must develop an approach to rapidly acquiring new expertise as such expertise becomes necessary. The panel recommends that the division acquire this expertise from industry, university laboratories, and other government laboratories by funding sabbaticals at NIST for the required experts when the need arises for their competence. . . ." (p. 32).
Division Response: Expertise is acquired through CRADAs and collaborations with industry, universities, other government laboratories, national laboratories, and consortia and through

faculty hires (including sabbaticals) and students and guest researchers from universities, other government laboratories, and the semiconductor industry. The challenge for the division is not to necessarily increase the number of collaborations but to effectively manage them to maximize the return on investment of time, staff, and resources by both parties.
1995 Panel Comment: The panel reiterates that acquiring new expertise and increasing ability to respond to market needs is the greatest challenge facing EEEL and the division in the immediate future. A well-articulated strategy on how EEEL and the division plan to increase agility is needed.

1994 Panel Recommendation: "The panel endorses the strategy to allocate a small fraction . . . of STRS funds to basic science research. However, these activities should be evaluated yearly for their contribution to the strategic metrology mission. Basic research activities that do not show relevance to the NIST metrology mission within a reasonable period (2 to 3 years) should be terminated to develop new initiatives . . ." (p. 32).
Division Response: EEEL conducts fundamental research as an integral part of many of its measurement-development projects. Most of the fundamental research projects that EEEL pursues are focused on topics likely to have outcomes benefiting measurement development for U.S. industry. That is, EEEL conducts directed fundamental research. EEEL does not bound the amount of directed fundamental research that it conducts to support its measurement mission. It may also conduct some fundamental research that is not directed toward potential outcomes benefiting measurement development. The criteria for identifying a suitable project are (1) unusual opportunity for high impact, and (2) some special reason for EEEL to be a performer.
1995 Panel Comment: The panel reemphasizes the need to evaluate progress and relevance of all projects within the division on an annual basis.

1994 Panel Recommendation: "The panel recommends that EEEL further develop its strategy for project selection, considering published methodologies such as the portfolio-based methodology . . ." (p. 32).
1995 Panel Comment: The division provided no written response. The project selection criteria presented are optimized on a project level, not a portfolio level. It is evident from the division's 1995 presentation that awareness of portfolio management is heightened relative to last year, but a coherent response or plan is apparently not forthcoming.

Electromagnetic Fields Division

Mission

The Electromagnetic Fields Division develops and evaluates systems, devices, and methods for measurement and analysis of radio frequency electromagnetic fields, signals, noise, interference, and properties of materials for guided and freely propagating fields, including frequency and time domain representation of electromagnetic fields and their interaction with materials and structures; provides essential measurement and calibration services, enabling industry and government to solve important national, commercial, industrial, and military problems such as evaluating the performance of microwave and millimeter systems, components, and materials used, for example, in advanced radar, satellite and mobile communications, and automated test systems; assists other agencies with measurement-related issues such as determining levels of nonionizing radiation and solving electromagnetic interference problems; and disseminates results to industry, universities, and other government agencies to foster effective research, development, manufacturing, and marketplace equity.

Resources

Fiscal year 1994 funding for the Electromagnetic Fields Division totaled $10.3 million, of which $5.2 million was from STRS, $0.5 million from ATP, $1.2 million from fees for calibrations and other services, and $3.4 million from OA. Fiscal year 1995 funding was estimated at the time of the assessment to total $9.5 million: $3.9 million, STRS; $0.4 million, ATP; $1.2 million, calibrations and other services; and $3.9 million, OA. Of a total staff of 71, 44 are technical professionals, and 18 hold a PhD degree.

Assessment of Priorities and the Priority-Setting Process

The division's priority-setting and priority-shifting methodologies need improvement. During fiscal year 1994, the division attempted to react to new metrology demands. Historically, this division has been funded primarily by other agencies, principally the Department of Defense (DOD). With such funds decreasing, with only modest increases in STRS funding, and with substantial calibration services requirements, the division has been unable to readily shift priorities among programs to meet new requirements. One alternative is the solicitation of new funding from the NIST-wide initiative process; unfortunately, the initiative process is excessively long. The division needs a more timely method of evaluating the relevance of programs, adding and eliminating programs, and reassigning and retraining personnel. With a 3-year gap between the submittal of a funding initiative and the receipt of the funding, it is imperative that the division anticipate industry's need at least 4 years in advance. Despite this, planning must be completed quickly to give the organization a clear set of goals and plans.

The highly successful recent workshop, "Electromagnetic Interference and Electromagnetic Compatibility (EMI/EMC) Metrology Challenges for Industry," suggests the division should develop an EMC initiative for fiscal year 1997, provide feedback to industry on the basis of the workshop, and hold additional workshops to provide further guidance as the initiative develops. One way for NIST to help industry with EMC issues is to become involved with International Electrotechnical Commission technical committees. NIST is highly regarded internationally as an unbiased and competent organization and could have great influence. Many metrology issues are involved in the new electromagnetic standards being developed internationally. The priority list developed at the EMI/EMC workshop received widespread support, and the division must respond to these as soon as possible or lose credibility. The division can also act as a catalyst for the EMC industry, helping steer industrial work toward desired results by acting as expert consultants to form and oversee industry committees. This action would receive leadership support from industry, as most industries would be flattered to say they consulted with NIST on a particular issue.

The division has been actively investigating the ways in which it can contribute to industry's needs in the rapidly expanding field of wireless communications. The division should consolidate the knowledge gained and prepare an initiative on wireless as soon as feasible. This initiative, and the funding that should result from it, would strengthen and further encourage interaction among the three groups that make up the division, since an initiative on wireless would include, for example, microelectronics metrology within the Microwave Metrology Group, the electromagnetic properties of materials and antenna mutual coupling effects within the Antenna and Materials Metrology Group, and a variety of emissions and immunity metrology issues within the Fields and Interference Metrology Group. A workshop similar to the EMI/EMC workshop would be an excellent way to obtain industry input on pressing needs and to help set priorities for the wireless area.

The division should reexamine the value to its current and future activities of providing extensive routine calibrations to industry. It should also examine possible alternative ways of producing traceability to NIST and transfers to industry. The division should move, wherever possible, in the direction of reducing routine calibrations.

Assessment of Technical Programs

The division has ongoing programs in power standards and measurements; impedance, attentuation, and voltage standards and measurements; network analysis and measurement; metrology for microelectronics (inexpensive and accurate electrical measurement methods for high-speed and high-frequency microelectronic devices); noise standards and measurements; development of electromagnetic reference fields and transfer probe standards; emission and immunity metrology; antenna measurement theory, metrology for antenna, radar cross section, and space systems; and measurement of electromagnetic properties of dielectric and magnetic materials. In addition, the division provides calibrations and special test measurements to industry and government laboratories The division's technical programs are generally good, and the quality of the work continues to be of the high standard that has always been NIST's trademark. The equipment and facilities are adequate for current programs but may require significant updating as the division continues its transition from OA support to support by private industry The division needs a roadmapping process to define these requirements in advance of actual need The division's programs overall are effective in reaching goals and in transitioning technology to industry. However, some efforts are not in the direction needed by industry.

The panel notes the receipt of the prestigious Institute of Electrical and Electronics Engineers (IEEE) Morris E. Leeds Award by two members of the division's technical staff, which is a well-deserved recognition for their pioneering and basic work on microelectronics metrology. The panel encourages further support for future extensions of this activity, particularly in interconnects and package effects, and the crosstalk effects that can result

Assessment of Impact on Industry

The division's technical work has traditionally had a limited nondefense impact, as much of this work has been related to DOD needs The division is in a transition from being heavily

DOD supported to being more commercially oriented Although the division's balance of programs is still weighted towards defense, opportunities to support private industry are numerous and diverse. Customers of the division could include the commercial satellite communications industry, the telecommunications industry, and the cable television industry. The current focus on wireless technology, personal communication, and information transfer should provide a good environment for making this transition. Many of the division's skills, including EMC, antenna metrology, and noise measurements, are very appropriate to these new technologies. As the division shifts its programs to commercial applications, it must make more effort to ascertain industry's critical needs.

One area where the division does supply significant industrial support is in calibrations of both antennas and components. The availability of standards that have known error bounds and are traceable to national standards has a very positive impact on the competitiveness of U.S. industry. A quality assurance process might enhance the value of this service to industry.

The Antenna and Materials Metrology Group is heavily dependent on OA funds and, as a result, the majority of its work is DOD related However, the commercial satellite industry is very strong and intensely competitive. There should be opportunities for NIST to provide metrology support for this industry and as a result make U.S satellite manufacturers more competitive in the world market. Specific opportunities include more accurate gain measurements, more accurate polarization measurements, and more accurate pattern measurements. A key contact would be INTELSAT, an international organization that has driven many of the improvements in satellite antenna metrology. The panel recommends that the division initiate contact with INTELSAT to define opportunities to improve the competitiveness of U.S. manufacturers.

Recommendations

The following are the panel's recommendations for the Electromagnetic Fields Division.

- The Electromagnetic Fields Division should complete its roadmap exercise as promptly as possible to clarify its goals and plans

- The division should invest more effort in ascertaining industry's critical needs as it continues its transition from providing defense-related to commercial support.

- The division should follow up on its recent EMI/EMC workshop with a fiscal year 1997 initiative in EMC.

- A workshop similar to the EMI/EMC workshop should be held to give direction to a division initiative in wireless communications.

- The division should consider a quality assurance process for its calibrations and other services to industry.

- The division should consider alternate means of providing routine calibration services to industry.

- The division should better familiarize itself with industry's metrology requirements through greater participation in international standards committees and conferences and visits to U.S. industry.

- The division should initiate contact with INTELSAT to define opportunities to improve the competitiveness of the U.S. commercial satellite industry.

Electromagnetic Fields Division Responses to Fiscal Year 1994 Recommendations

The panel finds the Electromagnetic Fields Division generally responsive to its 1994 recommendations, quoted from the fiscal year 1994 assessment report below. The division should be complimented for its efforts in gathering information and data necessary to develop a systematic roadmap for future technology needs, for its controlled reduction and upgrading of the staff, and for organizing an industry workshop on EMI/EMC metrology needs. Of special note is the division's action to expand work on monolithic microwave integrated circuits (MMICs) into the Microelectronics Metrology project, which reflects increased emphasis on microelectronics packaging and interconnections

1994 Panel Recommendation: "Commercial applications based on microwave frequencies should lead to a large number of metrology issues involving microwave integrated circuits, antennas, and electromagnetic compatibility. The Electromagnetic Fields Division should be positioned to support U.S. industry in these emerging technologies and applications, emphasizing the development of low-cost transfer standards and calibration techniques that are easily used by industry" (pp. 35-36)
Division Response: The division has recognized that industry needs measurement techniques that are both accurate and cost effective and has been interacting with industry to develop and improve measurement techniques to meet these criteria. In support of MMICs, the division has developed calibration techniques that are based on compact calibration sets that use imperfect resistors and lines typical of commercial MMIC devices. The division continues to distribute user-friendly on-wafer calibration and measurement software and has enhanced it to ensure compatibility with a wider range of commonly used instrumentation. The division is working on alternative methods that will reduce time and expense for providing electrical traceability for S-parameter measurements in both coaxial and waveguide transmission lines. With respect to antenna measurements, the division is evaluating a self-calibration/mirror image technique that could reduce costs by a factor of two for calibrating low-cost transfer probe and horn standards and is investigating an infrared holographic method for the measurement of antennas that shows promise for rapidly collecting planar near-field data and for on-line diagnostic testing in an assembly line environment.

1994 Panel Recommendation: "The division should consult with relevant industrial organizations to assess what new measurement problems and needs for new standards are expected to arise from new microwave applications and then prepare a systematic roadmap and develop appropriate initiatives . . ." (p. 36).

Division Response: The division's staff members are continually seeking input as they interact with representatives of industry at conferences and in standards activities and as they visit individual laboratories. The division has also participated in formal workshops and planned others such as the EMC/EMI workshop. Each group is developing a long-range plan for all its technical areas, providing references for industrial needs, and prioritizing each area. This information will then be combined to form the division roadmap. A microwave element responding to new applications in industry is being considered in fiscal year 1997 initiative development.

1994 Panel Recommendation: "Vehicle collision-avoidance systems operating at millimeter wavelengths and extensively utilizing microwave integrated circuits will be on the market in a few years. Since the division has the special calibration knowledge and skills required to solve issues arising from these applications, the division should survey manufacturers to determine NIST's support and develop the appropriate initiatives" (p. 36).
Division Response: The division is measuring and analyzing 60 GHz planar near-field data on a prototype subarray that will be used as an element for millimeter-wave arrays. This project includes both theoretical analysis and implementation and is expected to show that the probe-position error correction methods developed for these higher-frequency measurements are sound. A proposal to investigate terahertz frequency metrology methods and devices has been prepared and is being considered in fiscal year 1997 initiative development.

1994 Panel Recommendation: "Many different types of antennas will be required for new commercial applications, but in some cases . . . a proliferation of communications and radar functions will be present simultaneously. Antennas of different types operating at different frequencies will lead to an unprecedented number of mutual coupling effects. The division should be sensitive to new technical issues arising as a result and consider initiating new measurement programs to identify and help solve such problems" (p. 36).
Division Response: The division has done work in the past on modeling mutual coupling between co-sited antennas, and much of that work will apply in this application. The division is also studying coupling in lossy multimode transmission line systems that will apply to the integrated circuits and transmission lines used in these systems. An equivalent circuit theory applicable to multimode systems has been developed and mask sets with test structures, laid out. Fabrication of structures is planned for fiscal year 1995.

1994 Panel Recommendation: "New commercial applications require improved metrology in electromagnetic compatibility involving measurements for both immunity and emissions. The division has not developed a systematic roadmap for these issues based on its own technical judgment and surveys of industrial needs. Such a strategic planning approach should be supported by appropriate levels of funding and staff" (p. 36).
Division Response: The division has conducted extensive industrial surveys to identify first-hand, up-to-date information on the measurement-related needs and problems associated with electromagnetic compatibility. This survey identified about 50 technical issues that U.S. industries face as they compete in the global marketplace and advancements needed in EMI/EMC metrology research. In January 1995, the division conducted a workshop entitled "EMI/EMC Metrology Challenges for Industry" to prioritize the advances needed in EMI/EMC metrology and develop a systematic roadmap.

1994 Panel Recommendation: "The division should provide leadership in electromagnetic compatibility, since there is no industrial organization representing that area. In this context, the division should be proactive in helping to prepare U.S. industry to meet the new European Union EMC standards, including standards harmonization, EMC metrology, and EMC calibration standards" (p. 36).
Division Response: The division actively participates in many standards committees in the IEEE, American National Standards Institute (ANSI), Society of Automotive Engineers, and American Society for Testing and Materials. Group members have played a major role in developing many cost-effective EMC standards. Some of the EMC standards adapted by ANSI were proposed to the International Special Committee on Radio Interference as international standards.

1994 Panel Recommendation: "The division should determine the support it can provide to the information superhighway on issues such as EMC, antennas, microwave integrated circuits, and other technologies" (p. 36).
Division Response: The division has received funding from the NII initiative to support work in characterizing interconnections. The division is applying its expertise in on-wafer calibration to the development of calibration techniques for the time domain systems most commonly used in testing these information networks. The division is also pursuing other work associated with the wireless aspects of this technology.

1994 Panel Recommendation: "The division should consider retraining existing staff and hiring new staff, particularly younger staff, to address new applications. There should be some overlap of new staff with retirees to provide continuity in key technologies" (p. 37).
Division Response: The division has begun the process of retraining, has reassigned staff to the Noise project and the Microelectronics Metrology Program, and anticipates more reassignments. The division is also considering hiring a new person to assist in the Microelectronics project if funding continues.

1994 Panel Recommendation: "In anticipation of new increases in STRS funding and OA funding decreases, the division should systematically examine which programs will continue to increase and which should be phased out or reduce in scope. . . ." (p. 37).
Division Response: The division is carrying out such an analysis as one component of long-range plan and roadmap development.

Electromagnetic Technology Division

Mission

The Electromagnetic Technology Division develops and promotes advanced physical standards and measurement methods for the magnetics, electronics, and superconductor industries and their related scientific communities; employs phenomena based on magnetics, superconductivity, and cryoelectronics to create new measurement technology and associated standards and apparatus; advances the state of the art by basic research and development of requisite materials, fabrication techniques, instrumentation, underlying theory, and data for metrology; provides new measurement methods, instrumentation, imaging and characterization tools, and standards in support of the magnetics industry; develops measurement technology to determine basic properties of magnetic materials and structures with support from theoretical studies and modeling; collaborates with the magnetic recording industry in development of metrology to support future recording heads and media with their ever-increasing data density; uses the unique properties of superconductors and cryogenic electronics to invent and improve measurement methods for electromagnetic signals ranging from static voltages and magnetic fields, through audio, microwave, infrared, visible, and x-ray frequencies; leads the international community in setting standards for measurement of superconductor parameters; and provides the metrology infrastructure needed for the industrial development and application of superconductors, both large and small scale.

Resources

Fiscal year 1994 funding for the Electromagnetic Technology Division was $6.92 million, of which $4.88 million was from STRS, $0.64 million from ATP, and $1.4 million from OA. Fiscal year 1995 funding was estimated at the time of the assessment to total $6.91 million: $4.89 million, STRS; $0.45 million, ATP; and $1.57 million, OA. Of a total paid staff of 49, 40 are technical professionals and 26 hold a PhD degree.

Assessment of Priorities and the Priority-Setting Process

The division appears to be setting priorities effectively. Magnetics projects have been selected on the basis of the technical needs and requirements of the current magnetics technology, mission, and capabilities and skills of available personnel. Ongoing dialogs between division staff and industrial and university colleagues have in many cases led to projects that were selected for their high potential impact and relevance to industrial and scientific needs. During the past year, the magnetics program has been built up by redirecting some staff members. Assignment of priorities in the development of low-temperature instrumentation is based on standards activities. This work is essential and central to NIST's mission. The single-electron tunneling research at Boulder, which could lead to a quantum standard for capacitance, is a particular example of an effort that should move forward under stable funding. Work on superconductor standards development and representation of U.S. interests in international standards activities are of ever-increasing importance, but the present level of staffing in this area is not representative of its potential impact.

There is a particular challenge associated with priority-setting for projects supporting the magnetics and superconductivity industry. These industries are rapidly moving and highly competitive, and much of the key technology developed in industrial laboratories is retained as proprietary. Inadvertent duplication of this work at NIST diverts scarce resources from understaffed projects. Particular attention to this is necessary in the areas of giant magnetoresistive heads, pinning in alloy superconductors, and superconductor interfaces in thin films.

The magnetics program should be part of a larger EEEL- or NIST-wide recognition of the importance of information storage (magnetic, optical, semiconducting, ferroelectric, and so on) as an industry. There does not seem to be a process in place to encourage the formation of cross-divisional teams to identify and address the needs of this industry.

The panel is concerned over the laboratory's lack of recognition of the importance of low-temperature measurements as a priority. It has been clearly demonstrated over the past 20 years that many electrical measurements are best made at low temperatures. The collective impact on the capabilities of NIST in the metrology and standards arenas has been vastly enhanced by the low-temperature research of this division at both Boulder and Gaithersburg. A deliberate decision should be made at the laboratory level to increase, maintain, or shrink these activities to an appropriate size. The present situation, in which the budget of the Boulder group appears to be frozen, resulting in the loss of one staff member per year, is demoralizing a division that is a unique national asset.

Assessment of Technical Programs

In most cases, the current work within the division's projects is at the leading edge of such research worldwide and, in some cases, has led all such efforts. Equipment and facilities appear to be mostly adequate, but if projects are maintained at their present size, more space should be obtained.

The addition of a disk recording test stand and vibrating sample magnetometer would add substantial value to the division's program by allowing direct recording performance of components such as novel heads and disks of different microstructure to be quantified

The panel notes with concern the growing use of postdoctoral personnel in positions that are in the critical path of important projects in magnetics and low-temperature measurements. If these temporary personnel are not retained, their knowledge will be lost and the investment required to create that knowledge will be wasted Another unintended effect of the continued hiring of postdoctoral personnel is an imbalance between the number of scientists and engineers in the division, since engineers do not traditionally seek postdoctoral positions. Many efforts, such as the high-resolution x-ray detector and the scanning micromagnetic recording system, would benefit from the presence of more hands-on development engineers As hiring opportunities become available, consideration should be given to supplementing the division's traditionally strong physics base with additional graduate-level electrical engineers

If an assistant division chief is added, the panel suggests that the management team should be balanced by a person with engineering experience either in magnetics or, more broadly, in information storage. Such a person would allow the current magnetics group to take leadership in defining NIST's relationship to the information storage industry.

An office in information storage, including magnetics, similar to the Office of Microelectronics Programs, could be part of the responsibilities of a deputy chief. This office could serve to maintain heightened awareness within NIST of storage industry technologies and roadmaps and general awareness of market-related requirements in the information processing and storage industries, and it could help to organize meetings, as appropriate, to examine additional areas of opportunity in magnetics and storage, such as perpendicular recording, contact recording, or magnetic studies for the health care industry (recently identified by NIST as an umbrella initiative area for fiscal year 1997).

The project management structure used in this division, without group leaders, seems to be working well and is consistent with the modern industry practice of eliminating middle levels of management. It has the advantage of allowing senior technical people more involvement in the decision-making process, while still giving them enough time to maintain their unique technical skills at the laboratory bench.

With the reorganization of the Electromagnetic Technology Division, EEEL has made a clear statement that every effort will be made to enhance and enlarge the magnetic and storage programs. This is evidenced by growth for magnetic storage in the fiscal year 1997 budget plan; interaction with industrial storage standards and technology organizations, such as the International Disk Equipment and Materials Association (IDEMA) and the National Storage Industry Consortium (NSIC); the plan for the division to be the primary focus of the NIST initiative for magnetic storage; and its interactions through the NIST Industry Fellows Program with companies such as the Maxtor Corporation (Longmont, Colo.).

The quality of the magnetics projects in the Electromagnetic Technology Division is high, as evidenced by the number of ongoing collaborations with industrial, governmental, and university counterparts (for example, IBM, Quantum, Hewlett-Packard, Censtor, Micropolis, Maxtor, NSIC, Stanford, University of California at San Diego), and the external visibility received by NIST scientists at external conferences and meetings. Developments of particular interest include the scanning near-field optical microscope, which has the potential for revolutionizing the ease with which high-resolution magnetics measurements are made; the scanning magnetic recording system, which could potentially find broad application as a research, development, and eventually a manufacturing tool; high-resolution scanning microscopy for head and media applications; and the correlation of microstructure with magnetic performance and deposition conditions. The division should continue to develop magnetic microscopy tools with detailed comparison with theoretical modeling calculations. Successful development of these tools could have broad application across the industry. In general, the equipment for the magnetics projects is sufficient.

In the Superconductor Standards and Technology project, the interlaboratory comparisons of critical current (I_C) and the development of I_C simulators are central to the orderly growth of the superconductor industry. The division's work in these areas is of high quality and is appropriate. There currently exists no coherent U.S industrial leadership in the development of international standards for commercial superconductors, and NIST must assume leadership in this area. Unfortunately, the present level of divisional staffing and support is insufficient to compete effectively with a large Japanese effort. If this level is not supplemented in the next year, the result may be Japanese domination of the international standards in this critical area. Supplementation should include adding staff dedicated to this effort and providing financial and organizational support and involvement of representatives of industry and other government agencies such as DOD and DOE. Work on artificial pinning centers in NbTi, although of excellent technical quality, falls outside the NIST mission and should not be continued past fiscal year 1995.

In the Superconductor Interfaces and Electrical Transport project, determination of the effect of strain on critical current in bulk superconductors is an area in which the division has historically excelled, and this work should continue. Particular focus on rapid evaluation of high-temperature superconducting (HTS) materials and devices is essential to continued progress in conductor development.

Research on interfaces in bulk superconductors should focus on high-current, low-resistance contacts to HTS wires and on the development of superconducting splices between such wires. The division is uniquely qualified to address these areas, and success would enable a number of applications both in instruments and large-scale devices. An initiative on interfaces of thin film HTS materials has recently been funded by the Office of Naval Research and the National Science Foundation at a number of institutions, and a body of proprietary knowledge in this area exists in U.S. industry, so care must be taken to avoid duplication of these efforts.

The measurement of ac loss in superconductors and the development of instrumentation to accomplish this in the Magnetic Instruments and Materials Characterization project is an appropriate and timely activity. However, the diversion of personnel from this effort to magnetics has postponed construction of the flux integration magnetometer designed for these measurements. Given the rapid evolution of superconductors designed for reduced loss, this delay has had an immediate effect on the industry.

The Nanoscale Cryoelectronics project, the Josephson Array Development project, the High-T_C (critical temperature) Electronics project, and the High-Performance Sensors, Infrared Detectors, and Mixers project represent the invention, creation, and development of the devices that make measurements at low temperatures first possible and then more accurate. This work is of the highest quality. These projects are staffed by a unique assembly of highly talented individuals which, as a team, represents an asset for NIST and for the nation. Simply stated, there is not a comparable center of excellence elsewhere, either in a university, industry, or other federal laboratory. This center of excellence has had great impact on the mission, capabilities, and reputation of NIST itself

Assessment of Impact on Industry

NIST's traditional impact on industry has been as a provider of fundamental standards. In magnetics, the division's program is below critical mass and has only limited impact. In superconductivity, however, the division provides basic low-temperature metrology which underlies the needed fundamental standards for this area of technology. As a result, the work of the division has significant indirect impact on industry. The impact of this division in large-scale superconductivity is greatest in those areas where NIST provides unique facilities or measurement capabilities and furnishes timely feedback to industry. Examples are work on development of standards for commercial superconductors and measurements of the effects of strain on I_C.

Projects focused on low-temperature measurements have had great industrial impact. This ranges from the transfer of the voltage standard for manufacture by a small U.S. company to many valuable one-on-one collaborations. The value of the former is easy to measure, but the latter is also significant and important.

It is clear that the U.S. superconductor industry, previously based on low-temperature superconducting materials, is beginning to expand because of recent discoveries of high-temperature superconducting materials. Four new high-temperature superconductor companies employ over 300 people and continue to expand. Their technology is advanced enough to develop some products but remains fragile and immature. As the industry continues to grow, it will be increasingly important for the division to take on the role that other EEEL divisions play for more mature industries such as semiconductors, by providing standards, measurements, and leadership in international standard setting.

Recommendations

The following are the panel's recommendations for the Electromagnetic Technology Division.

- The addition of a disk recording test stand and a vibrating sample magnetometer would add substantial value to the Electromagnetic Technology Division's program by allowing direct recording performance of components to be quantified.
- EEEL should consider an office in information storage, similar to the Office of Microelectronics Programs, to leverage NIST programs in service to the storage industry.
- A cross-divisional or perhaps cross-laboratory initiative should be considered to explore and address the needs of the information storage industry.
- The present magnetics projects should be recognized as a priority for that industry, and should be staffed and financed appropriately.
- Work on artificial pinning centers in NbTi falls outside the NIST mission and should not be continued past fiscal year 1995.
- The importance of low-temperature measurement techniques should be recognized and a staffing and budget plan be put in place to maintain the national asset represented by these projects at Gaithersburg and Boulder.
- The program to develop a magnetometer for the measurement of ac losses in superconductors either should be abandoned or should be pursued with sufficient focus to ensure timely completion of the device and the availability of staff to operate it.

Electromagnetic Technology Division Responses to Fiscal Year 1994 Recommendations

Below are the panel's 1994 recommendations for the Electromagnetic Technology Division, quoted from the fiscal year 1994 assessment report, followed by the division's response.

1994 Panel Recommendation: "The . . . [division] should have one mission and strategy statement that is well understood by all staff. This should focus work on fewer, key projects, and lead to stable staffing for those projects. Resources in superconductivity should be limited . . ." (p. 46).

Division Response: At the time of the fiscal year 1994 panel meeting, the separation of the Optoelectronics Division from the Electromagnetic Technology Division was still in the planning phase. The restructuring of the new division has proceeded over the year, although progress has been slower than originally anticipated. The restructuring has concentrated on a number of key projects with strong researcher/project leader management. A new mission statement has been prepared which recognizes an increased commitment to providing support to the magnetics industry while maintaining world leadership in selected aspects of superconductivity.

1994 Panel Recommendation: "The single-electron tunneling activity needs to switch from competence-building funding to stable core funding. Funding and staffing for this project should be stabilized at an adequate level and this project made a core component of any NIST-wide activity in this area" (p. 47).
Division Response: The SET activity was begun in 1987. The importance of the work was recognized with competence funding, to continue through this fiscal year. A complementary program was begun in 1992 by the Electricity Division. That project is also competence funded, with funding through 1998. Researchers in the two divisions have established a working relationship that both division chiefs regard as excellent.

The restructured Electromagnetic Technology Division is broadening the focus of its work with a new project called Nanoscale Cryoelectronics to develop novel integrated circuits for metrology based on the unique properties of submicrometer electronic devices operated at temperatures below 1 K. The project has been augmented with a National Research Council postdoctoral research fellow, who will focus on the development of SET-based metrology, including prospective capacitance standards. The division plan calls for hiring a second postdoctoral researcher to work on a novel x-ray detector. The division is also seeking to hire a researcher of world renown for the general area of nanoscale cryoelectronics. The division recognizes that identifying funding sources for the standards applications of SET work is important and that this focus of the work needs to be nurtured.

1994 Panel Recommendation: "With the development of superconducting materials and instruments that operate without a liquid cryogen . . . there is an enormous need for techniques and procedures to give quality assurance in the 10 to 77 K range. . . . It is important that EEEL anticipate and adequately support the needs of the new division in this area" (p. 47).
Division Response: All of the project areas involved with large-scale applications of superconductors are either using or building systems for measurement studies at temperatures above 4 K. Specifically, instrumentation and temperature-variable systems for developing critical current standards, measuring field-orientation dependence of I_c, determining ac loss, and measuring strain effects in coils are all either in place or will be in fiscal year 1995. The NIST superconductor simulator, which enables the testing of instrumentation apart from the cryogenic system, is an important tool for the development of these systems by industry. EEEL's role as a leader in the international standards community in this field ensures involvement in associated standards development.

1994 Panel Recommendation: "Work on high-T_c materials and processing should be focused on specific processes and device structures related to the division's core mission. More generic

activity should be deemphasized, since it is less likely to have an impact and will greatly dilute resources" (p. 47).
Division Response: The focus in this program areas is changing along the lines suggested. The high-temperature superconductor junction work emphasizes application to voltage standards, and the bolometer work focuses on radiometer applications in collaboration with the Physics Laboratory. The microwave applications program has ended its work in tunable devices and, at the request of the industry, is starting a collaborative program on the development of metrology leading to improved devices. Measurement methods for interface resistance continue to be improved, and two new industry collaborators will be added to the effort in fiscal year 1995.

1994 Panel Recommendation: "The division should obtain a sample preparation apparatus, or convert an existing one, for dedication to magnetics" (p. 47).
Division Response: Purchase of a deposition chamber for magnetics was initiated even before this recommendation. The new apparatus will have extensive analysis capability, including an ultra-high-vacuum scanning tunneling microscope. Many parts have been received. Assembly will take place shortly in a newly remodeled laboratory.

1994 Panel Recommendation: "The division should decide if storage-oriented work should be expanded according to its fiscal year 1992 plans; if not, it should be discontinued. . . ." (p. 47).
Division Response: Work is expanding at a reasonable pace given the realities of resources and facilities. The NIST/EEEL reputation in magnetics research and metrology grew significantly over the past year, and many companies, both large and small, requested either research collaborations or assistance with measurement problems. The program in magnetic recording metrology developed with a focus on recording heads, especially magnetoresistive and giant magnetoresistive heads. A series of informal seminars was held with speakers from industry and organizations such as university recording centers. In addition, EEEL initiated a joint seminar with the Physics Laboratory in Gaithersburg using EEEL's new teleconferencing facility. EEEL initiated an interaction with IDEMA and is discussing possible approaches to participation in its standards efforts. ANSI protocol standards remain in the domain of the Computer Systems Laboratory and are probably not now appropriate for EEEL participation. EEEL maintains a strong interaction with the ATP-funded project on recording heads at the National Storage Industry Consortium and has interacted with the ATP awardee Nonvolatile Electronics (Plymouth, Minn.) in the imaging of memory systems.

Optoelectronics Division

Mission

The mission of the Optoelectronics Division is to provide the optoelectronics industry and its suppliers and customers with comprehensive and technically advanced measurement capabilities, standards, and traceability to those standards.

Resources

The fiscal year 1995 funding of the Optoelectronics Division was estimated at the time of the assessment to total $7.0 million: $5.7 million from STRS, $0.1 million from ATP, $0.1 million from fees for calibrations and other services, and $1.1 million from OA. Of 41 staff members, 32 are technical professionals, and 20 hold a PhD degree.

Assessment of Priorities and the Priority-Setting Process

The priority setting and project selection at the division level follow a somewhat informal but nevertheless correct approach. Not only are current customer needs assessed, but these assessments are also validated by direct feedback from representatives in the specific fields where the demand for services is generated. In addition, future needs are anticipated by studying industry trends, resulting in a good balance between projects for mature technologies and projects for emerging technologies.

In 1 year, the division has gone from inception to being a fully operational entity. This is a great accomplishment and an example of a degree of responsiveness not commonly found in a government agency. The panel congratulates EEEL management and all others who helped to make this transition possible. During fiscal year 1994, this new division redirected a number of ongoing activities and launched new thrusts that are well aligned with industrial needs. The division is sharpening its focus on metrology and is doing excellent work.

The optoelectronics industry is growing rapidly and is the key leverage point for future information transport. The division will have many challenges and opportunities to assist industry in the coming decade. The division needs to maintain each of its efforts at critical mass wisely and, in a timely manner, transition to new important projects, such as erbium doped fiber amplifier (EDFA) characterization, and seek additional resources, both financial and personnel, to tackle other aspects of photonics that cannot be pursued at present.

The division's process of holding quarterly R&D reviews should yield good results in terms of program focus and in effectively reallocating resources throughout the year as necessary to optimize the division's achievements

The division should consider programs in optical storage and display technology, photonics packaging (including materials), and in situ measurements of optical growth of new devices (for example, blue lasers). The Optoelectronics Division should take the lead in defining and launching programs in these areas and coordinate with other divisions as appropriate to serve as the main NIST point of contact for this industry

Assessment of Technical Programs

The most notable achievement in the Source and Detector Measurement project is the characterization of photodetector frequency response out to 60 GHz to high accuracy. This effort was cross-referenced to work at the U.K. National Physical Laboratory and is representative of the type of collaborative metrology work the panel believes serves industry well. Efforts continue on power meter calibration and optical power measurement. The panel applauds new efforts in source characterization, such as work on vertical cavity surface emitting lasers. This work should lead to important metrology for advanced semiconductor lasers.

Metrology efforts within the Fiber and Integrated Optics project are highlighted by development of SRMs for fiber cladding diameter measurement and the completion of an international round-robin on measurement methods for fiber geometry. This has benefited U.S. fiber manufacturers by enabling them to determine the accuracy of their own measurement techniques. Standard Reference Materials for fiber coating diameter measurements and ferrule size are also under development; these efforts should be equally beneficial to industry. Efforts to develop and characterize SRM fibers for measurements of chromatic dispersion and polarization mode dispersion are being expanded. A new international round-robin on characterization of EDFAs is especially noteworthy. Collaboration across groups in the division should make this a very valuable activity as the importance of EDFAs in deployed communication systems grows.

The development of wavelength standards in the 1510 to 1540 nm range in the Fiber and Discrete Components project is very important. As the effort is extended to 1540 to 1560 nm, the standards should prove invaluable to companies developing wavelength division multiplexing components for next generation fiber communication systems. Work on fiber Bragg grating devices is of high quality and interfaces well with the high-accuracy wavelength calibration standard.

In the Optical Fiber Sensors project, work on iron garnet magneto-optic sensors is excellent and has been coordinated with a domestic materials supplier. Ongoing efforts in sensor standards and sensor components should be examined for alignment with and priority relative to the division's plan.

The Dielectric Materials and Devices project has two major focuses. The first is materials metrology. Characterization tools being developed for determining uniformity of optical properties on $LiNbO_3$ wafers are sorely needed by industry. The division is strongly encouraged to work closely with industry in this activity. The other major focus, development and characterization of rare-earth glasses and associated integrated optic lasers and amplifiers, is well recognized and of high quality. This focus should continue to have a strong emphasis on waveguide material characterization

The Semiconductor Materials and Devices project focuses most of its effort on epitaxial materials growth and characterization and has a small effort in devices. The panel finds this allocation very appropriate. The emphasis on in situ growth monitoring and spatially resolved surface and interface characterization of diode laser structures was based on substantial industry input. Initial experimental results in these areas are very encouraging. Close coupling with industrial workers as this project progresses will help ensure a high value to U.S. industry.

Assessment of Impact on Industry

The impact of the division's work is reflected in publications such as the recent scatter diagram showing results of the multinational cladding diameter measurement comparison (*Technical Digest, Symposium on Optical Fiber Measurements* [NIST SP 864], 1994, pp. 129-132; Fiber Geometry: Results of an International Interlaboratory Measurement Comparison). The diagram shows that U.S. manufacturers are superior vendors because of their tight process control, and this publication will give industry worldwide the incentive to converge. Results of other programs have been directly evaluated by customer feedback from participating industries. For example, wavelength standards work and the polarization standard were extremely well received by customers.

In developing closer collaboration with industry, the division should develop multiple-pronged approaches separately tailored for both large and small companies as appropriate. This is necessary given the mixed profile of optoelectronics companies in the United States.

Recommendations

The panel's fiscal year 1995 recommendations for the Optoelectronics Division are as follows.

- The impact of the Optoelectronics Division's work should be measured in terms of improvements over time in industry and by tracking the demand for related services and reference material by the customers.
- Since shifts in the relatively new and dynamic optoelectronics industry are quite common, these shifts should be observed and followed as appropriate. This action puts emphasis on having and following a somewhat formal new project selection process.
- The division should develop multipronged strategies to accommodate both large and small industrial collaborations.

Optoelectronics Division Responses to Fiscal Year 1994 Recommendations

The panel's 1994 recommendations for the Optoelectronics Division are given below, quoted from the fiscal year 1994 assessment, with the division's response. The 1995 panel notes that all 1994 recommendations have been acted on. Most have been implemented, and some are in the process of being reprioritized because of technology shifts in industry. Most notably, the division has refocused itself toward the mission of metrology and away from "science for science's sake."

1994 Panel Recommendation: "The . . . [division] should consider potential needs related to displays, optical computation/interconnect, ultrahigh-speed (tera-bit) technology, and soliton measurements" (p. 41).
Division Response: During the latter part of fiscal year 1994, the division became more active in both intermediate- and long-term program planning, and that emphasis continues. Members of the division have made many visits to companies and universities to discuss advanced technology and future requirements. With regard to the specific technologies noted, displays have not been a part of the division's scope, but a part of the Electricity Division's Video Technology project. Optical computation and interconnects are of definite interest to the division, and a small effort in data interconnects has begun. Tera-bit technology is being addressed in NIST, but mostly by

other divisions. For several years, the division has been using soliton technology to develop high-speed waveform measurement systems based on optical sampling.

1994 Panel Recommendation: "The division should support a moderate effort on emerging technologies with fundamental needs for new measurement concepts, including high-speed technology up to 60 GHz, measurement needs for wavelength division multiplexing, and optical storage" (p. 41).
Division Response: The division is moving in the directions suggested. The division presently has the capability to perform both time- and frequency-domain measurement on detectors and modulators to about 50 GHz and is extending these capabilities to about 60 GHz. The new division structure includes a project on fiber and discrete devices, which is aimed in part at components for wavelength division multiplexing. The division agrees it has an important role to play in the optical data storage industry but has not yet been able to start a program.

1994 Panel Recommendation: "The division should maintain or expand significant efforts on technologies already in the manufacturing phase: (1) fiber measurements . . . (2) integrated optoelectronics . . . (3) measurements for sources, detectors, and amplifiers . . . (4) power measurement . . . and (5) optical sensors . . ." (pp. 41-42).
Division Response: The majority of the division's resources are focused in these areas, and the division actively contributes in almost every area mentioned. Division staff published approximately 40 papers and gave approximately 45 talks during fiscal year 1994, mostly in these areas. During the latter part of fiscal year 1994 and continuing into fiscal year 1995, the division has been working to understand better how it currently allocates resources among these areas in order to provide a basis from which it can make adjustments and expand contributions. Part of this effort involves potential collaborations with the Physics Laboratory.

1994 Panel Recommendation: "The division should continue to assess customer needs by maintaining direct contact with all major optical electronics industries and participation in standards groups" (p. 42).
Division Response: Division staff sit on approximately 18 domestic and international standards committees, either as a member or observer, and on several professional society boards and committees. Staff members serve on committees for several of the most important and relevant optoelectronic conference committees, and staff attendance at conferences is high. The division has about 12 ongoing collaborations with companies. Last year, staff noted over 75 significant telephone consultations with industry. Staff members participated actively in the Optoelectronics Industry Development Association roadmap process. NIST is cosponsoring, and two staff members are participating in, a Japanese Technology Evaluation Center study of the Japanese and U.S. optoelectronic industries, which involves visits to about 10 U.S. and 30 Japanese companies; other staff members regularly visit companies for informal exchanges of information. All of this requires over 150 trips by staff each year, most of which are documented in trip reports and available for program planning. Calibrations services are another source of industry input. In a typical year, the division serves 40 to 50 customers and discusses services with many others.

1994 Panel Recommendation: "The division should develop an external funding strategy for mature programs in order to use internal funds to expand support for critical areas, particularly those entering the manufacturing stage" (p. 42).
Division Response: The division definitely needs to develop a more coherent external funding strategy, but it may not be as simple as using external funds for more mature technologies. Historically, the division has been more successful in identifying external funding for advanced technologies and, as the technologies matured, was able to shift their support to internal funding. This was true of work in support of the sensor industry and is anticipated for work in the characterization of vertical-cavity surface-emitting lasers, which recently received funding from ARPA. In other technologies, where the division has obtained external funding for well-established programs, contract work must not divert efforts from advancing the state of the art of metrology. The percentage of external funding in this division is not burdensome at present, and the division hopes to increase external funding in each of the next several years.

1994 Panel Recommendation: "The division should clearly delineate the EEEL role relative to that of the Physics Laboratory in detector characterization and narrow-line laser diode characterization. Industrial pull on the existing capability should be a major consideration in resolving issues of organizational overlap" (p. 42).
Division Response: The respective roles of EEEL and the Physics Laboratory are presently being addressed at both the laboratory level and division level. With respect to Optoelectronics Division overlaps with the Radiometric Physics Division, visits of staff have occurred in both directions and discussions are ongoing. It is the position of the Optoelectronics Division that there are three major considerations in addressing organization overlaps: technical quality and integrity, service to customers, and efficiency.

1994 Panel Recommendation: "NIST requires a strategy for meeting the needs of the laser industry in industrial and medical applications. The . . . [division] alone does not have the resources to support needs ranging from short-wavelength lithography to medical welding and cutting applications. The division role should be defined in the context of the entire NIST effort" (p. 42).
Division Response: The Optoelectronics Division is to be the focus of optoelectronics research at NIST. However, a dozen or so other divisions have activities in optoelectronics and facilities or expertise that could be available to support the industry. There is a growing recognition within NIST that better coordination of these activities could result in greater support of the industry without additional resources, and therefore steps in this direction should be a priority. With regard to the ability of the division to support specific segments of the industry, the strategy is to attempt to apportion division resources according to industrial need and ability to have an impact.

Office of Microelectronics Programs

The primary activity of the Office of Microelectronics Programs is the National Semiconductor Metrology Program (NSMP). The mission of the NSMP is to apply NIST expertise to metrology needs of the semiconductor industries, to collaborate with industry in executing NIST's work and delivering its results, to coordinate metrological work among cooperating government laboratories, and to provide industry a path to government metrological expertise and activities. The funds made available to this program have grown from $1.5 million in fiscal year 1991 to $10 million in fiscal year 1995.

The panel applauds the strong collaboration between OMP and SEMATECH in the SIA Roadmap activities and the critical ownership OMP has assumed in forming the NSMP. Funded programs planned for 1995 generally align with the Roadmap, although some programs succeed more in this regard than others. The panel cautions that in an environment of increasing budget and new project initiation, there is potential for programs to be established without means for completion or termination based on a global strategic plan.

OMP priorities are clearly established based on relevance to the SIA Roadmap and currently existing expertise; examples include funded programs on electrical and thermal model development for integrated circuits and packages. Further strengthening of and emphasis on this activity are recommended by the panel. The current process for selection of projects is to exploit metrology capabilities throughout NIST. This initial approach is acceptable, but it is essential that the selection criteria rapidly migrate to need, with current skills a secondary rather than primary criteria.

Office of Law Enforcement Standards

The Office of Law Enforcement Standards (OLES) is under new leadership, a change that appears to be a positive force toward continuing the OLES tradition of working closely with law enforcement institutions and the industries that serve them. The fiscal year 1994 accomplishments as well as work planned for fiscal year 1995 appear to be closely linked to customer needs. The need for a modern firing range for OLES continues. A suggestion is to include such a facility in a new NIST building.

Mr. GUTKNECHT. Thank you, Dr. Rhyne.

Dr. Glaze?

STATEMENT OF DR. JAMES A. GLAZE

Dr. GLAZE. Thank you, Mr. Chairman and Members of the Committee. My name is Jim Glaze. I am the Vice President for Technology Programs for the Semiconductor Industry Association. I appreciate the opportunity to be here today to discuss the National Technology Roadmap for Semiconductors, which my organization has sponsored, and in particular the important role that the EEEL has played in both the planning and implementation phases of that work.

The SIA represents 32 U.S.-based semiconductor manufacturers. I think the total manufacturing production of that group is about 85 or 90 percent of all we produce in this country. Some 260,000 people work in the semiconductor manufacturing area. Perhaps more importantly, that effort underpins or enables a $400 billion electronics industry in this country. That industry worldwide, by the end of this century, will be the largest industry in the world.

Today, the U.S. semiconductor industry has a lead in market share of about 41 percent of the world market. I believe Japan is somewhere around 40, very close to us. To achieve that market share, our industry has spent an unprecedented sum of money in both capital investments and research and development. We spend about 20 percent of all revenues on capital and approximately 11 percent on research and development. That is amongst the highest, if not the highest, for any industry anywhere.

A little bit about the National Technology Roadmap for Semiconductors. Basically, in reviewing the needs of the industry in 1992, the SIA Board decided to establish a comprehensive review of all the semiconductor technology that would be required into the future that would provide a basis for future growth of the industry. As you know, semiconductor manufacturing is almost unimaginably technology intensive.

It was clear at that point, when that early 1992 initiative was established, that individual companies working individually would not be able to develop the methodologies and develop the pathways necessary for our industry to move forward, just because of the vast technology content.

In November of 1992, basically, technical experts from all parts of the semiconductor industry, including the producers, the suppliers, the customers, the government, and universities, got together to develop what was called a common vision of the course of semiconductor technology over the next 15 years. This product was basically called the National Technology Roadmap for Semiconductors.

In 1994, SIA reconvened this group, some 300 or more people, and revised this Roadmap to extend it one more generation beyond the 1992 time line. Basically, from a technical point, that extends the evolution of semiconductors down to 0.07 micron sizes, an almost unheard of number, from today's 0.35 micron design rule.

The purpose of the Roadmap is to provide a quality database of needs and a framework by which the semiconductor industry and those in government and academia associated with the semiconductor technology can systematically approach this enormous research and development requirement. SIA's intent is for the Roadmap to address a common national need for achieving both commercial competitiveness and defense preparedness, dual use, if you will.

There are many internal programs in microelectronics sponsored by the Departments of Defense, Commerce, and Energy. The Department of Commerce, through its NIST laboratory, has played a key role in developing standards in other cross-cutting technologies that are of key importance to our industry. Not only that, they have played a key role in defining these requirements and have played a key role in managing the roadmap process. I believe the Director of EEEL sits on our Roadmap coordinating group.

This agency, it is our opinion, should continue to be the focal point for development of advanced standards and metrology technologies and should represent a stake in the ground for our industry on these areas.

There are three aspects of NIST that are critical to our industry. Number one, NIST's technology standards formulation, implementation, and dissemination capabilities, which have been discussed at length before.

Two, NIST's ability to work with foreign governments. Tom Rhyne has expressed, standards are often used by countries as a non-tariff barrier.

Finally, NIST's scientists. NIST's staff is a valuable expert resource for our industry. The development, maintenance, and dissemination of standards is a complex and difficult task which is far too large for any single company to undertake. If such a company were to undertake it, it would no longer be a pre-competitive but it would become a competitive force, which would be for the disadvantage of our entire industry. NIST's staff acts as expert, independent arbitrators to resolve difficult programs in setting or using these important standards.

The current National Semiconductor Metrology Program under EEEL was formally established by NIST in 1994. It had its roots in a semiconductor initiative begun earlier, in 1991. Cognizant of the fact that the production of semiconductors require numerous measurements and the semiconductor devices are becoming increasingly complex so that the industry's measurement needs are constantly becoming more complex, as well.

If you look at the way we break out the various tasks within the National Roadmap, we break them out into eight technology focus areas. Every single one of those areas have substantial requirements for the metrology and standards, and so the participation by NIST has cut across—that's why we call it cross-cutting—every single area of our thinking and planning on the technology pathways to future progress.

I would say, to this end, the EEEL and the National Semiconductor Metrology Program serve a very critical function for our industry and we strongly support continued, or, I should say, future commitment to the organization and to the National Semiconductor Metrology Program. We would like to see in 1997 full funding, as recommended by the SIA and others, of at least $25 million a year. This is a relatively small number, but the leverage that we gain from this organization gives many, many times the amount of money this country invests. Thank you.

[The prepared statement of Dr. Glaze follows:]

STATEMENT OF

JAMES A. GLAZE

VICE PRESIDENT, TECHNOLOGY PROGRAMS,
SEMICONDUCTOR INDUSTRY ASSOCIATION

ON BEHALF OF

THE SEMICONDUCTOR INDUSTRY ASSOCIATION

BEFORE THE
SUBCOMMITTEE ON TECHNOLOGY
OF THE
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

JUNE 25, 1996

STATEMENT OF
JAMES A. GLAZE
VICE PRESIDENT, TECHNOLOGY PROGRAMS, SEMICONDUCTOR INDUSTRY ASSOCIATION

JUNE 25, 1996

Madam Chairwoman, my name is James A. Glaze, and I am the Vice President for Technology Programs at the Semiconductor Industry Association (SIA). I appreciate the opportunity to share with the Subcommittee SIA's views on the evolution and utility of the National Technology Roadmap for Semiconductors, the participation of the Electronics and Electrical Engineering Laboratory (EEEL) of the National Institute of Standards and Technology (NIST) in the Roadmap process, and the role of EEEL in meeting the metrology needs of the U.S. semiconductor industry.

SIA represents 32 U.S.-based semiconductor manufacturers. Since its founding, SIA has been actively engaged in issues of technology development and policy as they affect the industry as a whole.

The U.S. Semiconductor Industry

Semiconductors are an increasingly pervasive aspect of everyday life, enabling the creation of the information superhighway and the functioning of everything from automobiles to advanced medical equipment. Semiconductors are also the linchpin underlying this nation's advanced military weapons systems. A growing proportion of the value of these systems is dependent upon electronics products – up to 40 percent in some cases. The current design of the F-16 Fighter, for example, includes 17,000 electronics components. They are also intrinsically important in radars, weapons guidance and control systems.

U.S. semiconductor makers employ 260,000 people nationwide. Their products are the enabling technology behind the nearly $400 billion U.S. electronics industry, which provides employment for 2.5 million Americans.

The U.S. semiconductor industry is currently the world market share leader, with 1995 world sales reaching $59 billion, representing almost 41 percent of the $144 billion world market. Moreover, the world semiconductor market is expected to double by the year 2000, with projected sales of over $300 billion.

U.S. semiconductor producers are highly committed to maintaining their lead in both semiconductor manufacturing and technology. The U.S. semiconductor industry devotes on average 20 percent of its revenues to capital spending and another 11 percent to research and development – among the highest of any U.S. industry.

The National Technology Roadmap for Semiconductors

Background: With the formation of SEMATECH in 1987, SIA greatly expanded its efforts in supporting technology development for the industry. Combined with the Semiconductor Research Corporation (SRC), an SIA consortium that supports university research, the resulting impact on improving the technical capabilities in the industry was substantial. In reviewing the needs of the industry in 1992, the SIA Board decided to establish a comprehensive review of semiconductor technology and provide a basis from which industry, government, and academia could cooperate. This built upon the work of the National Advisory Committee on Semiconductors (NACS).

In November of 1992, technical experts from all parts of the semiconductor industry, including semiconductor producers, suppliers and customers, government, and universities came together to develop a common vision of the course of semiconductor technology over the next fifteen years. The product from this pioneering effort was the *National Technology Roadmap for Semiconductors* detailing industry trends, requirements, and obstacles for broad segments of semiconductor manufacturing technology.

Acceptance and utilization of the technology Roadmap by the semiconductor community has been overwhelming. In 1994, the Roadmap was revised to extend the timeline one more generation beyond that of the 1992 Roadmap to .07 micron technology requirements in 2010.

Policy: The purpose of the Roadmap is to provide a quality database of "needs" and a framework by which the semiconductor industry and those in government and academia associated with semiconductor technology can systematically approach the enormous research and development required to meet those needs. "Needs" are requirements on technology that allow the semiconductor manufacturing and supplier industries to maintain performance growth. The Roadmap defines these needs hierarchically. First, overall roadmap technology characteristics are set forth to show the top level of needs. Then individual technology roadmap sections prepared by the eight Technology Working Groups (TWGs) define additional levels of needs specific to each technology area.

Each TWG represents one of the technologies of direct interest to semiconductor product development and manufacturing operations. These critical technologies are: (1) Design and Test, (2) Process Integration, Devices, and Structures, (3) Environment, Safety, and Health, (4) Lithography, (5) Interconnect, (6) Materials and Bulk Processes, (7) Assembly and Packaging, and (8) Factory Integration.

The TWGs have also identified technology needs that extend into related disciplines closely aligned with the interests of suppliers, universities, and national laboratories. These "Crosscut Technologies" include metrology, modeling and simulation, electronic materials, standards, contamination-free manufacturing, and quality and reliability.

Because it is important to know what technology approaches are currently under consideration, in addition to the needs identified by the TWGs, the Roadmap also identifies some potential or alternative technologies. However, it should be emphasized that the Roadmap does not dictate which options are preferred or which should be pursued by the research community (and their funding agencies). Instead, the intent of the Roadmap is to enhance communication and facilitate innovation to meet the needs identified in the Roadmap.

SIA's intent for the Roadmap is to address a common national need of achieving both commercial competitiveness and defense preparedness (dual-use). Moreover, this national need can best be achieved through the cooperative efforts of participating technology leaders from industry, government, and academia. This can provide a solid foundation for independent or collaborative efforts throughout the nation to advance semiconductor technology. Only through government participation as a partner in this technology assessment process can the semiconductor technology base be fully and effectively exploited.

This policy also challenges the industry to achieve its technology objectives through existing organizations and with no significant increases in the current levels of investment as a percentage of total output. It is SIA's goal to make the best use of available U.S. resources, encourage the alignment of government programs consistent with the Roadmap, and rely upon the existing national research structures and institutions to implement recommendations.

Of course, in a field as dynamic as semiconductor technology, it is impossible to predict the future. To be of ongoing utility, the Roadmap will require regular updating as the future terrain becomes more clearly visible. SIA's plan is to examine the Roadmap regularly – probably by reconvening technical experts every couple of years to keep it current and vital. The goal is to have a set of charts that all parties working within or associated with the industry can consult when examining their research and development priorities.

Strategy: The Roadmap provides a framework that can enhance collaboration, increase shared knowledge, and minimize duplication of efforts. But implementation of the Roadmap will require investments by both industry and government. Investment vehicles will include internal research and development programs by semiconductor manufacturers and their suppliers, industry and industry/government consortia, government agencies and special government/industry programs that target critical civilian, defense, and defense conversion needs. Below is a summary of some of the programs that address Roadmap objectives.

Industrial R&D: The U.S. semiconductor industry and its suppliers invest around 11 percent of their annual revenues on internal R&D. This rate of expenditure is among the highest of any industry in the nation. For the most part, these internal programs address technologies that can be incorporated into manufacturing over a one to three year time frame. This industry invests more than $5 billion dollars annually in R&D, including over $90 million annually in SEMATECH and over $35 million in SRC.

Government Agencies: Internal programs in microelectronics are sponsored by the Departments of Defense, Commerce, and Energy. The Department of Defense, especially through ARPA, has played a vital role in the development of advanced microelectronic technologies. These programs – ones that have a five to ten year time horizon – best serve the Roadmap mission by addressing precompetitive high-risk technologies with no short-term commercial return and that are, therefore, often beyond the means of industry alone to support. The Department of Commerce, through its NIST laboratory, has played a key role in developing standards and other "cross-cutting" technologies in support of microelectronics manufacturing. This agency should continue to be the focal point for development of advanced standards and metrology technologies. The Department of Energy, through the National Laboratories, has sponsored numerous electronics programs in support of their defense mission. These programs are now becoming available to the commercial sector. Moreover, laboratory leaders are actively aligning these programs to the Roadmap.

The National Institute of Standards and Technology

Because of the fundamental contributions technology is making to the nation's security, culture and economic growth, SIA believes it is essential that the U.S. government have an agency with the technical depth to understand and monitor advanced technologies. This function is currently performed by the Technology Administration of the Department of Commerce.

The agency within the Technology Administration whose work is essential to the SIA and the nation is the National Institute of Standards and Technology (NIST). Created as the National Bureau of Standards in 1901, NIST's mandate is "to help U.S. industry improve its competitiveness through new technologies, modernized production presence, improved quality control, and rapid commercialization."

Three aspects of NIST are critical to the U.S. semiconductor industry:

1. NIST's technology standards formulation, implementation and dissemination capabilities. U.S. industry must have nationally and internationally recognized technology standards for its products. As technology gets more complex and diverse, the need for accurate standards is growing. For example, the semiconductor industry achieves its increasing productivity in part by printing progressively smaller features. When in about five years the printed feature size of semiconductors reaches about 0.18 micron, industry will not have a standard method of accurately measuring these features in production. As discussed further below, joint NIST/industry program is addressing this problem.

2. NIST's ability to work with foreign governments. Standards are often used by countries as nontariff trade barriers. Often, the key to having a new system accepted in the world marketplace is establishing a worldwide standard. Without such a standard, a market is fragmented and market development is impeded. Countries frequently require imported foreign instrumentation and components to be re-certified, resulting in extra delay and cost. A country that can develop a standard with its industry acceptable worldwide can avoid the import re-certification requirement and gain a significant market advantage. NIST participates in government-to-government standard setting activities and thereby assists U.S. industry and technology development generally by ensuring that new standards meet U.S. interests.

3. NIST's scientists. NIST's staff is a valuable expert resource for U.S. industry. The development, maintenance and dissemination of standards is a complex and difficult task which is too large for a single company, and often is resisted by others in the industry because it gives the controlling company a competitive advantage. NIST's staff act as expert, independent arbitrators to resolve difficulties in setting or using standards.

The National Semiconductor Metrology Program

The current National Semiconductor Metrology Program (NSMP) – formally established by NIST in 1994 – had its roots in a semiconductor initiative begun in 1991. Funding for the NSMP doubled in FY 1995 to $10 million. While SIA supported a budget of $19 million for FY 1996, no funds were appropriated for this fiscal year.

The production of semiconductors requires numerous measurements, and as semiconductor devices are becoming increasingly complex, so the industry's measurement needs are constantly becoming more complex as well. The technology challenges facing the industry as semiconductor chips get smaller and smaller require measurement and characterization capabilities well beyond those now available. To this end, the NSMP serves a critical function for the industry, as well as for its customers both in the private sector and the government – especially the Department of Defense. SIA therefore supports funding for the program of FY 1997 of $25 million. As the funding policies of both ARPA and SEMATECH have recently changed, even at this full funding level, the program's costs are small in comparison with both the size and needs of semiconductor technology development in the United States.

The NSMP supports measurement development programs in a number of important areas for the semiconductor industry, including:

- trace moisture in process gases;
- pressure, composition, and flow rate of process gases;
- physical and chemical properties data for modeling chemical reactions;
- boron implants in silicon;
- surface microroughness of silicon wafers;
- intensity of ultraviolet light for making fine patterns on water surfaces;
- dimensional measurements for patterns on the surface of silicon wafers;
- properties of polymers for device packages; and
- improved high-temperature thermocouples.

As a result of the NSMP, a number of advances in metrology of value to the semiconductor industry have been made, including: the establishment of highly accurate electrical measurements of alignment between successive layers of materials, equipment to determine absolute moisture measurements in gases to extremely low levels, standard reference materials for oxygen and boron in silicon, calibration services for ultraviolet lightmeters, greater knowledge of electrically driven film deposition processes, and a better understanding of the manner in which scattered light from highly polished surfaces inhibits the detection of small contaminating particles.

The Electronics and Electrical Engineering Laboratory at NIST

The Electronics and Electrical Engineering Laboratory (EEEL) at NIST provides metrology support for the electronics industry in areas such as electronic instrumentation, semiconductors, magnetics, superconductors, microwaves, lightwaves and video display technology.

EEEL has provided assistance in the development of measurement technology to the semiconductor industry for forty years. For example, the EEEL microwave program developed new measurement techniques based on transmission line test structures formed directly on semiconductor wafers. This work uncovered significant errors in traditional measurements. The U.S. industry, through adoption of these new measurement techniques, has greatly increased its productivity.

Most importantly to our industry, EEEL is leading the NIST interlaboratory effort to develop metrology to meet the needs of the semiconductor industry as identified in the Roadmap. The Office of Microelectronics Programs (OMP) at EEEL serves as the manager of the National Semiconductor Metrology Program. OMP is responsible for maintaining the relevance of the program's specific projects through direct industry contacts and regular interaction with industry consortia such as SEMATECH and SRC. OMP is also active in the Roadmap process through its participation in the Metrology Crosscut Working Group of the SIA. The Director of EEEL also serves as a member of the Roadmap Coordination Group. Each year OMP also participates in SEMICON West – the largest semiconductor industry trade show.

Currently, there are 23 projects being undertaken through the NSMP. These projects are all selected in conjunction with the semiconductor technology Roadmap and specific industry input to the various NIST laboratories.

Significant accomplishments of the program include:

- Demonstration of a high resolution x-ray spectrometer which will allow superior chemical identification of small particles and light elements while preserving the convenient operation necessary for practical use in semiconductor fabrication.

- Development of the first practical tool for measuring flatness on 300mm wafers by adapting a technique well-known in the optics industry to silicon.

- Development of an improved temperature measurement device (thermocouple) which is much more stable than existing devices while also providing three times the accuracy of current thermocouples at high temperatures – a critical ability in the semiconductor industry.

- Development of new measurement methods designed to prevent unpredictable wire bond failures – a major system reliability problem for the industry.

A critical area requiring the continued focus of the NSMP is in the field of metrology for next generation optical lithography. As outlined in the Roadmap, the industry is in need of suppliers that will be able to produce a viable advanced lithography tool to meet the industry's expected need for 180 to 130 nanometer lithographic technology. EEEL is working closely with the semiconductor industry and our suppliers to see that this need can be met.

As the above examples demonstrate, the National Semiconductor Metrology Program is serving important needs of the semiconductor industry which are not being met elsewhere. This program is critical for the future competitiveness of the U.S. semiconductor industry. It should be fully funded at $25 million for FY 1997.

Conclusion

Technology is the driver for economic growth in the world market to an unprecedented degree. The Asians and Europeans have the same "short list" of critical technologies as we do, including semiconductors.

The semiconductor Roadmap provides the medium to focus efforts throughout the nation on semiconductor technology development. But it is essential that industry and government work together as partners so that the Roadmap can be implemented in a way that benefits our nation from both an economic and security standpoint.

Mr. GUTKNECHT. Thank you, Dr. Glaze.

I would now turn to my colleague, Mr. Tanner. Do you have some questions?

Mr. TANNER. Thank you, Mr. Chairman.

I just wish the rest of the Congress could have heard this panel's testimony. I want to thank you for being here. I understand, Dr. Hebner, you came back from Europe. I got back from Sarajevo last night myself, so it's about 8:30, 9:00 to me, too.

Mr. HEBNER. I understand how you feel.

Mr. TANNER. Dr. Rhyne, thank you for your testimony. As I said in my opening statement, NIST is sort of the stealth agency of the Federal Government. Not that many people come into contact with it day to day, and yet it probably characterizes more than any other agency that comes to mind the idea that government ought to be an ally of business rather than an adversary and ought to help American businesses compete worldwide as the government, and the government can do something that is useful and constructive and contributes to the quality of the life of our citizens.

I think your testimony, better than I can say, points out just how critical the role that NIST plays as it relates to our standing in the world. Some way or another, we are going to try to continue to get that word across to people who have a different view.

Let me ask this question. The Omnibus Trade and Competitiveness Act of 1988 expanded the NIST mission a little bit beyond the traditional standards and metrology emphasis to more directly facilitate improvements in the competitiveness of U.S. industry. I know that we are talking about, with this panel, the laboratories and what the laboratories have done, and I certainly support everything you all have said and will do what I can to support the funding for this very vital work that is done.

But I'm also interested in some of the programs, the outreach programs at NIST to facilitate worldwide economic competitiveness by American industry. I guess my question is, in your opinion, has this activity diminished the ability of NIST to deliver these more traditional services? Have I characterized my inquiry good enough? I guess to Dr. Rhyne——

Dr. RHYNE. We agreed that Bob was going to answer all the questions.

[Laughter.]

Mr. TANNER. What I'm trying to get at——

Dr. RHYNE. I understand. I don't deal often in the names of the government acts, but I assume you're talking about programs like the MEP and the ATP and the TRP. When I was at MCC, I was involved in about 14 of the original proposals that came out of that group as a proposal manager and I think that those provided an excellent way for us at MCC to bring together kind of, at a nucleation site, a set of companies who otherwise would have either not dealt with that issue or they would have been competitors with less resources to be available.

So I'm familiar with the early days of what that program did within industry and I'm very familiar with the role that NIST played both in administrating it and facilitating it. As best I understand the organizational structure within NIST, there's enough—there's probably the appropriate amount of overlap and the appropriate amount of separation between individuals who are involved in managing and administering those programs.

I can say clearly that with regard to EEEL, that we had the same concern I believe you voiced. Would these big, high-funded, high visibility programs detract from the basic metrology and standardization efforts? I don't think we've seen such a detraction up until the 1995 assessment. I'm not hinting that there was one. As you know, because of some circumstances here, we have had only a very informal assessment process thus far in 1996.

In fact, I think the way in which a small percentage of those monies actually flowed out of those programs to be made available for sort of seed projects and other commercialization projects within the EEEL have really been, to some degree, a benefit. Sure, they have siphoned off some very good people to go over and administer it, but in the main, I think that NIST has done a very good job of—I think of the little python swallowing the big pig. It's been a very big effort to administer, but I don't believe to this point that I could report to you any diminution of the quality of the work on the basic NIST mission within the EEEL.

Mr. TANNER. Thank you.

Dr. Glaze, do you have a comment on that?

Dr. GLAZE. I don't have any insight into the inner workings. I look at it from the outside. Our interaction has primarily been through the metrology and standards setting activities of the National Metrology Center. That effort has been magnificent. It's been slowed by slowing of funding, but I don't see any lack of enthusiasm or any lack of progress from our point of view as a result of any of these other programs.

I'm aware of the other programs and generally know how they work, but I haven't—in fact, until you asked the question, it never occurred to me that there would have been a——

Mr. TANNER. I don't think there is, either, but there are some who have a different view of that than you and I.

Let me ask this. I agree with you that the Roadmap for semiconductors has been constructive. In your opinion, would this serve as a model for maybe some other high technology fields? Is there a place that we could go to work and maybe help NIST in other areas that we want the United States industrial base to be a world leader in?

Dr. GLAZE. Yes. It already has. I think the NEMI activity, the National Electronics Manufacturing Initiative, which is sort of a, if you were to imagine the Semiconductor Roadmap activity, basically, that model was used to extend across a vast area of electronics, from microwaves to batteries to all aspects of electronics. They basically were following the format. As far as I understand, NIST is playing a very similar role with regard to this initiative.

Also, if you take a piece of that, in the electronic packaging area, it turns out that electronic packaging, while it sounds mundane, is becoming a very, very big product enabler and value-added component to our industry. We lag the rest of the world in this technology area. Recently, there has been a major packaging effort that has used the Roadmap formula and has brought together all of the packaging houses in the United States into another Roadmapping activity, very similar to this semiconductor activity, and I believe

NIST will be playing a role, if they are not already, in a very similar way.

Fundamentally, when these Roadmapping activities get together and they turn to the metrology and to the standards area, there's no place else to turn because no single company has that mandate. So I wouldn't know where to go, setting up this Roadmap.

Mr. TANNER. Yes, sir?

Dr. RHYNE. I'll quote from the 1995 assessment of the EEEL, where the panel, as a broad recommendation about the overall laboratory, stated, "EEEL should expand its activities to assist additional industrial groups in the electronics and electrical engineering sectors in defining their need for metrology and related services, parallelling the work of the SIA and the SIA Roadmap."

In some sense, the strength of the SIA program can be viewed as a weakness in that they are so effective at extracting from the EEEL the services and support that they need that it has been a recurring concern of the panel that less organized areas of the U.S. industry aren't able to get that same level of support. I can't cite but a couple of examples.

I think in electromagnetic interference, in one of the video standards areas and in a couple of other areas, I think at least with the urging of the panel, the NIST EEEL management has begun to try to provide workshops which will bring together leaders in those industries to see if they can't use the model that's been put forward and used so effectively by the SIA to help define what their needs should be and what they should be getting from EEEL. So I think I totally agree with you.

Mr. TANNER. Dr. Hebner, do you have anything to add?

Mr. HEBNER. Two minor points. One, I guess I should mention that Jud French, the Director of the Electronics and Electrical Engineering Laboratory, is unable to be with us today because he is at the NEMI meeting to help them understand what the metrology needs are in the electronics manufacturing.

Second, I should also emphasize that we very carefully view our role in this area as working with industry. What we are trying to do is to encourage industry to think clearly about where they need to go and what technological advances they intend to make and then our role is to look at what they intend to do technically and try to understand and extract what that means for our national measurement system and to provide the measurement system that they can use to make the advances that they want.

So we obsessively look for the measurement aspects of their problem and the industry looks for the technology, the product development, all of the things that make them competitive. All we are—not all, but the critical role we are playing is that we use those exercises to help plan our metrology program.

Mr. TANNER. Like I said, I wish this Congress could hear what you all have had to say and others who come here. Maybe we ought to use the industry feedback, the industry input that certainly occurs at NIST on some other agencies of the Federal Government. People have this uncontrollable desire to attack sometimes, and I understand it, and the government gives them plenty of ammunition with which to fire. But this is a critically important area for this country and in the future and your contribution here today and what you've done in the past is appreciated. Thank you.

Mr. GUTKNECHT. Thank you, Mr. Tanner.

I have a couple of questions for Dr. Glaze. You talked about Technology Roadmaps. I understand they're prospective, but are there any potential drawbacks to these Roadmaps in other potential industries?

Dr. GLAZE. Drawbacks to other industries?

Mr. GUTKNECHT. Right. I mean, are Roadmaps always a good idea, the concept?

Dr. GLAZE. I think we've found them to be essential for our industry. I can't imagine any drawbacks in the process that we've used, and in view of the fact that many other industries are now emulating that process—there has been criticism, minor criticism by some that says, by doing a Roadmap exercise, you structure the future and perhaps stifle creativity. I think that particular concern is pretty baseless.

In doing our Roadmap activities, we do not specify solutions. We only specify what the needs are going to be to meet certain milestones to continue the productivity increases that this industry has provided. But we don't say that it must be achieved by this specific method. So we lay out primarily the requirements and the needs as opposed to the methods.

Mr. GUTKNECHT. Can a company gain competitive advantage and still stay on the Roadmap?

Dr. GLAZE. The work that the Roadmap addresses is what we call pre-competitive. In other words, it benefits all companies. One way to look at it, I think, is that the massive amount of R&D that industry spends, much of it is spent with the target of deployment within three years. In other words, industry is looking three years out, sometimes a little bit further than that out.

If you get much past three years, some three to six years—for example, we have created SEMATECH, the sort of help on a pre-competitive basis in a consortium manner, a common way of solving problems in the three- to six-year time frame. We look at university research, for example, as providing innovative solutions in the nine-year time frame and out, say, for example.

So if you look at the very, very broad spectrum of research needs, there's a very specific role for both in-house competitive research that companies will use to gain a competitive advantage and the pre-competitive research for which no single company can execute but which all companies within this pond, this industry, require.

I don't know if I answered the question. The answer is that to remain competitive, my feeling, you're going to have to participate at the pre-competitive level in this technology because as a single company, you won't be able to do it yourself.

Mr. GUTKNECHT. Dr. Glaze, I want to thank you for speaking in plain English. You've been helpful. I'm still not sure that I completely understand this concept, but I think I understand it better than when you started.

Dr. GLAZE. The concept of pre-competitive?

Mr. GUTKNECHT. Right.

Dr. GLAZE. For example——

Mr. GUTKNECHT. Yes, give an example, if you could.

Dr. GLAZE. The example is that, basically, the design rules, for example, in laying out the transistors on a piece of silicon, the tooling of the metrology, the chemicals, and the processes are in common use throughout the industry. You do not go to Intel and find that they are using one unique set of lithography tools or one unique set of chemicals or one unique set of processes. They compete on design, performance. But the suppliers in our industry carry a similar technology base out to the entire industry, and it's those elements of the technology that are common to all and that's what we mean by pre-competitive.

Mr. GUTKNECHT. I think I understand it now. Thank you.

Dr. GLAZE. Okay.

Mr. GUTKNECHT. Dr. Rhyne, you mentioned that the major problem was a mismatch of funds and needs, and you used the term technology triage. Can you expand a little on that and how big a problem it is?

Dr. RHYNE. The thing that we've seen repeatedly when we've sat down with the managers of the projects at maybe the second-tier level within the EEEL, moving away from Jud, away from the division managers, and we've had people sit down with the specific project managers, is that they have lots and lots of project ideas, ideas that each and every one considered, whether from a social point of view, a technical point of view, whether it serves industry or what, looked very good. But the resources consistently are inadequate to meet this ever-expanding area of electrotechnology.

We use terms like DC-to-daylight. I mean, you are talking about such a range of industries. The electric utility guys think that 61 hertz is high frequency, and the guys over here building computers think that five volts is high voltage. So it's just a tremendous span of work to be done and each of these industries is finding that the metrology techniques that they used up until now are no longer available and appropriate.

Dr. Hebner mentioned the common meter in the home. I mean, there's a device that you manufacture for a very small amount of money, I think less than $10, probably, in current dollars, and yet it works without problems for decades, if not for 100 years. But the way in which people are using electric utility consumption right now is arguing that some differences need to be provided in the way we measure how much you actually use. What exactly are we going to count as a kilowatt hour when you're using only a portion, maybe, of the 60-cycle wave form?

All of these things are being thrown on the table and what the managers are trying to do is to listen to the industry requirements and respond by starting projects that, albeit maybe in a three to five year lifetime, not a 20-year lifetime, but those projects have to prepare the metrology capabilities so that U.S. industries will be able to use those capabilities to produce products not only nationally but internationally at some point in the future.

Having watched the process and watched the projects that get stopped and the new projects that do get started, there's so much film left on the cutting room floor, if you want an analogy. There's just a lot of good stuff that I'm sure they would like to do. It's easy to—there are very few problems you can't solve with more time, money, or people. I'm not here to try to tell you that you need to—

you've got a lot of problems that are hard to meet with the monies available. I sit on a local school board in Texas, and so I deal with this in a miniature way.

But I will tell you that with what they've got, the thing that we are always impressed with is how well they are matching their capability, their resources to those needs, but it is inevitably a decision making process that leaves good ideas behind, and I think what you and I ought to be worried about, I'm sure what their management worries about all the time, is are they going to miss something today that we really wish had been started in a few years.

That's why I said earlier that in those areas where the industry is better organized, as in Jim's area, which is actually my own area, that there we're getting the right kind of support. It's in the areas that the industries are somewhat disparate, not well formed together, that I think all of us worry that they're not going to identify the future metrology needs and we may miss some critical area that will be of major national importance in the future.

Mr. GUTKNECHT. I want to thank you. We sort of perform triage around here, and we call it prioritization sometimes, but I'm certain that your concerns are well founded. I'm amazed myself at how well you guys do in terms of keeping ahead of a constantly-changing world of technology out there.

I would say, though, for the record, just looking at the raw numbers in terms of the appropriations, I think the bill that Bob Walker put together and took to the House floor and hopefully is going to be negotiated with the Senate does call for increasing spending in all the categories, or at least spending as much as the President had requested, and in many categories we're actually increasing it. But there's always unlimited demands, particularly in this field, and we do congratulate the folks at NIST and the work that they do.

I think, Dr. Hebner, your analogy was a good one, and I think we as Members of Congress should expropriate that and use it, that there are really two fundamental responsibilities of the government, and that is to create a medium of exchange, some kind of currency, and then secondly, some system of weights and measures, if you want to get down to the basics. But as we go forward and as those weights and measures get more and more complicated, I do congratulate the work that you do to try and stay ahead of that in this field.

I have no further questions. Unfortunately, the Chairwoman, Mrs. Morella, has not returned. If there are no other further questions or business to come before the Subcommittee, I will call this Subcommittee meeting adjourned. Thank you.

[Whereupon, at 2:44 p.m., the subcommittee was adjourned.]

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